AERIAL PHOTOGRAPHY

A COMPREHENSIVE SURVEY OF ITS PRACTICE & DEVELOPMENT

By
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and
F. L. WILLS, F.R.P.S.

with a Foreword
By
SIR ALAN J. COBHAM, K.B.E., A.F.C.

and Introductory Notes
By
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and
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AUTHORS' PREFACE

THE advent of the aeroplane opened up a new field for photography, and from the moment when camera and 'plane were used in co-operation it was found that an entirely fresh development of photographic practice had been brought into being. It is with this development that we are concerned in the present volume. The subject has been covered, we hope, in a non-controversial way—at least we have endeavoured so to treat it, for in several of the many branches of aerial photography there are rival schools of thought and sometimes conflicting schools of practice. This is inevitable in all experimental conditions. We have, however, maintained as far as possible a broad and unbiased view of the whole subject, recognizing the need for tolerance in the hope of presenting to the reader a work unhampered by narrow prejudices but supported by our own experience and the best experience of others.

Aerial surveying, a somewhat provocative branch of our subject, has been similarly dealt with; and we have not forgotten that, strictly speaking, the work in Britain might be more accurately described simply as aerial mapping.

Aerial survey proper covers operations in unexplored and partly explored regions where maps do not already exist or where they are not to be relied upon. Successful aerial surveying depends upon close co-operation with the ground surveyor.

That this branch of the aerial photographer's work will widen the scope of aeronautics generally is only just beginning to be acknowledged, although some authorities, notably Mr. C. G. Grey, editor of *The Aeroplane*, have long been drumming it into influential but frequently unreceptive quarters.

It is to experience and to research that this book is due. We have received help from many sources, official and private, in Britain, in European countries generally and in the United States of America. We have encountered many difficulties, but, on the whole, we have met

with generous encouragement and practical assistance. Our indebtedness is due particularly to the following:

The Royal Canadian Air Force, the United States Army Corps, Mr. O. G. S. Crawford, B.A., F.S.A., (Archæological Officer, Ordnance Survey), Mr. T. Thorne Baker, F.R.P.S., Mr. Hamilton Maxwell, Mr. Ronald C. Kemp, Mr. F. P. Raynham, M. Raint (Compagnie Aérienne Française), and Mr. Ellwood Wilson (Fairchild Aerial Surveys, Canada Ltd.). Other acknowledgments are made in the text.

In conclusion, we hope that we have omitted none to whom acknowledgment should have been given; we hope, too, that the result of our endeavours to present accurately and fairly the case for aerial photography has not fallen too short of our original ideals.

THE AUTHORS.

January, 1928.

FOREWORD

BY

BY SIR ALAN J. COBHAM, K.B.E., A.F.C.

WHEN Mr. Wills first asked me to write a foreword to the book on aerial photography that Mr. Clarence Winchester and he have written, I hesitated for a moment, because I thought that the introduction to such a book should come from some far greater technical authority than myself; but with thoughts of aerial photography, my mind ran back four or five years to the time when I was actively interested, in fact, making my livelihood out of aerial photography and survey. It was a desperate struggle in those pioneer days, because, apart from the difficulties that arose from lack of technical experience and scientific development that any new industry or trade might suffer from, we had an exhausting job to sell the idea of air survey and aerial photography to those whom we knew it ought to interest. And so with these thoughts in my mind, I came to the conclusion that possibly as one of the early pioneers who went through the days of great struggle in those dark years immediately after the war, I was, perhaps, qualified to write a foreword for this book.

Aerial photography and air survey are two distinct branches of a great new science, and perhaps the real start of this work came about in the late war when vertical aerial photographs were taken by the R.F.C. of the enemy's territory behind the line. It was discovered that by joining up these vertical photographs a complete photographic map was obtained of the whole front. Although the science of air survey developed rapidly during the war, there was still much room for improvement when, in 1918, many well-meaning and courageous men who had worked on aerial photography all through the war, decided to apply this new development to commercial and civil uses.

Let me explain that air survey deals with the mapping of the

earth's surface by means of aerial photography, and rendering a photographic map of the earth from above, or in some cases ordinary survey maps from a series of oblique aerial photographs.

Aerial photography, other than air survey, embraces a number of things, such as oblique photographs of factories, country estates, civil works, power plants, building sites, etc., which may be taken either for commercial, publicity or utility uses.

Every credit is due to those who have made air survey and aerial photography what they are to-day, namely, a science, an art and an industry all in one. Their early work and struggles were hardly what could be termed commercial, and had there not been in those who fought to keep aerial photography alive immediately after the war, a great deal of a "labour of love" attitude, I am afraid that to-day the world would not have been enriched by this new development.

Therefore, all honour is due to Mr. Wills, who has survived all difficulties, and managed to make his company pay its way, and at the same time help to educate the public in the uses of aerial photography.

I can remember in 1920 when I was piloting for aerial photography, how, although our idea was air survey, we were only too glad to get any sort of aerial photography job. The ground surveyors complained about its inaccuracy, and they were conservative and did not take the matter quite seriously. The real trouble was that the average ground surveyor could not see the possibilities in air survey, and the aerial photography firms knew far too little about general survey work to introduce new methods of applying their new science. It was not until some of the younger of the ground surveyors started to be interested in aerial photography that the real development came, and then the ground surveyor began to see possibilities that were beyond the scope of the original aerial surveyors who had started the industry.

Thus, to-day, we find that invariably every big air survey company has on its staff some important ground surveyor upon whom it must rely as a technical consultant on the big air survey contracts. It was a young surveyor who, after a flight in an aerial photography machine, and the taking of a few oblique photographs from an

aeroplane in Canada, hit upon the idea of surveying and mapping Ontario by a system of overlapping oblique photographs on the grid system from which maps were afterwards plotted.

Thus Canada to-day is being mapped twenty times faster than it has ever been done before, by means of aerial photography, and a hundred times more accurately; so much so that all the original survey maps of Ontario have had to be scrapped, as the air survey maps have proved them to be so terribly inaccurate.

Already parts of the earth have been mapped by air survey where they could never have been mapped from the ground, and at last Governments, concessions and companies in undeveloped parts of the world are realizing that it will be possible, by using the science of air survey, to open up territories many years ahead of the time that they would have been developed by means of the old ground survey system above.

Air survey has been most useful in the mapping of inland water country, vast swamp districts and impenetrable forest regions, because the aeroplane passes over a disease-infested area without risking the lives of men. A great railway engineer said a little while ago that in many parts of the world, where he had constructed railways over poorly surveyed territory, those railways would have cost far less to construct had he in his day been able to avail himself of the use of air survey.

There are many sides to aerial photography, and although air survey is the future great development, we must not forget that oblique commercial aerial photography has kept the industry alive through the lean years. Beautiful aerial pictures of country estates, townships, cathedrals, industrial plants, etc., have been taken in hundreds all over the country, and used for commercial purposes. Please note that I said aerial pictures, not photographs, for there is a vast difference between a photograph and a picture. I have called this new development a science, an art, and an industry; and this is where the art comes in, for as a rule there is just one angle to take a site from that makes it a picture and not a mere photograph.

Aerial survey and aerial photography are helping the development of aviation, because as the Public continue to see pictures of

the earth from above, and aerial maps or pictures are continually being used, the world becomes more air-minded. I think that air survey is of greater importance to Britain than almost any country in the world. The opening up and development of territories within the Empire can now be carried on at a far greater rate than was ever dreamed of in the past, by means of air survey, and I look upon it as an advance guard of civilization and exploration.

Clarence Winchester, has associated himself with the development of aviation for years; he was one of the pilots who flew long before the war: F. L. Wills has done a lot of good work in the cause of aerial photography. This is one of the first standard works ever written on this subject and will be a gift of knowledge that has been gained by sheer experience, to the coming generation who are going to take up this new science and industry.

AERO-SURVEYING OF FORESTS

BY

SIR PETER CLUTTERBUCK, C.I.E., C.B.E.,
Timber Adviser to the High Commissioner for India.

ONE of the most convincing examples of the practical value and enormous potentialities of aerial photography is to be found in the aero-photo survey and mapping of the forests of the Irrawaddy delta. This remarkable work was accomplished early in the year 1924, at about one-half the cost and in about one-sixth the time that would have been required for a land survey by ordinary methods. Even more important is the fact that the air survey was more accurate than ground surveying could have been under the prevailing conditions, and the aero-photo maps contain a wealth of detail which it would be economically impracticable to record by any other means. Sandy wastes, grass-covered areas, scrub, and the different kinds of forest are easily and definitely distinguishable one from another on the aero-photographs, so that the latter make possible an immediate estimate of the areas of various types of forest and other vegetation. It is even possible to form, from the photographs, a more accurate estimate of the general quality of the forest, and the extent and manner in which it has been worked, than could readily be obtained by observation from the ground.

The reserved forests covered by this survey extend to just over 1,000 square miles, and about 350 square miles of waterways and unclassed forests were also included in the survey. The contract for the work was accepted by Mr. R. C. Kemp, late Chief Inspector of Civil Aircraft to the Government of India. The seaplane used for the survey, a DH9 service aeroplane fitted with special floats, was piloted by Major C. K. Cochran-Patrick, D.S.O., M.C., and the photographs were taken by Flying Officer J. Durward. Ground control, the preparation of rectified mosaics, and the fair mapping were under

the control of Major C. G. Lewis, R.E.; while Messrs. C. W. Scott, D.F.C., and C. R. Robbins, M.C., D.F.C., of the Forest Department, were deputed to examine the photographs and compare them with the actual types of forest on the ground.

Altogether 3,795 plates were exposed, flying at an average height of 9,400 feet, resulting in a scale of 3·4 inches to 1 mile. The number of air photos averaged 260 per 100 square miles and, though atmospheric conditions were far from favourable, at least half the prints were of the highest quality and no difficulty was experienced in mapping the entire area. It is estimated that at least £19,000 was saved by the use of aerial survey and the saving would, of course, be proportionately greater in subsequent surveys using equipment already available.

Over a district such as the Irrawaddy delta, intersected by innumerable waterways with shelving banks of soft mud, and overgrown by vegetation through which a path has to be hewn foot by foot, there can be no question that aerial survey offers unique advantages. The results obtained have been more than satisfactory from every point of view, and the extraordinary clearness of field boundaries, in those photographs which include cultivated areas, indicate that the utility of aero-surveying and mapping is by no means restricted to forest, scrub and creek. How much wider are the possibilities, and what has already been accomplished in other directions, are shown admirably by the contents of this book.

AERIAL PHOTOGRAPHY IN RELATION TO RAILWAYS

BY

SIR FELIX J. C. POLE,
General Manager of the Great Western Railway.

THE use of aerial photography in relation to railways will unquestionably be of invaluable assistance to engineers engaged in laying out new lines in undeveloped regions, in foreign countries, where no reliable survey exists. In the first place, the whole of a large tract of country can be subjected to general inspection from the air, comprehensively and rapidly, with a view to determining the general conditions and the route offering best prospects of successful development. Next, any desired area can be photographed from the air in order to obtain detailed scale-maps, contoured if necessary. Then, during the work of construction, aerial photography affords a convenient means of obtaining permanent records of progress. The remarkable possibilities of aerial photography in these and other directions are shown clearly in this book.

In well-developed countries, ordnance surveys, or their equivalent, generally provide all the information required concerning topographical features of the countryside. Even so, the aero-camera can often be used to advantage in photographing goods yards, terminal stations, docks and other parts of a railway system and its auxiliaries, whether for recording the progress of construction, registering traffic conditions, or serving the purposes of advertisement.

In the British Isles, aerial photography frequently affords a means of securing beautiful views of places of interest not otherwise obtainable, whilst, in addition, the association of the science of flying with the art of photography has enabled railway companies to obtain views of considerable advertising value. In the future there will undoubtedly be an extensive use of this form of illustration for affording publicity to holiday resorts. It may be mentioned that the Great Western

Company have used aerial illustrations which show the extent of their South Wales Docks with a wealth of detail which could not be shown so attractively by any other means.

Perhaps the most striking feature of aerial photography is the extraordinary variety of the services in which it has already found application, as witness the contents of this volume. From the record of these achievements, inspiration and guidance may well be drawn for further developments.

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CHAPTER I

AIRCRAFT AND THE CAMERA

THE NAVIGABLE CAMERA PLATFORM

IT is not within the scope of this work to deal in detail or at any great length with the very wide subject of aircraft and the principles of aeronautics, but as we must later consider different types as carriers or platforms for the camera it may be as well to refer briefly to the development of flying.

Without power-driven craft aerial photography would have progressed but little, if at all, for the balloon offers insufficient directional control for prearranged and carefully planned schemes. Hence we may confine ourselves with safety to heavier-than-air machines, the development of which has made possible the considerable practice of aerial photography.

From the moment in 1809 when Sir George Cayley described a power-driven aeroplane which would undoubtedly have flown had an internal combustion engine been available, man has been progressing towards the final conquest of the air, though it was not until the end of last century and the beginning of this that any practical demonstrations were made. Wilbur and Orville Wright must ever be associated with the initial performances of note, although too little credit has yet been given to M. Ader, a Frenchman, who, in 1896, constructed the first power-driven 'plane that flew. The machine travelled only three hundred metres, it is true, but the achievement marked the first definitely practical step towards the controlled flight which is of such importance to the aerial photographer.

The Wright brothers followed the pioneering effort of Ader by constructing gliders, and finally making use of a 16 h.p. internal combustion engine. Their first flight with a power-driven machine

was made in 1903, and in 1905 they succeeded in remaining in the air for nearly forty minutes. Three years later Wilbur Wright came from America to Europe, and here achieved a flight of ninety-five miles in two hours, twenty minutes.

These figures are mentioned merely to show how swiftly man has advanced along paths of aerial achievement since the coming of the light internal combustion engine. Without such progress this book would never have been written and aerial photography would not to-day be recognized as an established science—one that is likely to trespass upon and influence more and more human activities.

As the photographer must use the navigable aerial platform, and as the results of his work must in many ways affect the public mind, it is desirable that he and the public should realize the debt they owe to the pioneers by whose efforts the navigable aerial platform came into being.

Until the war of 1914-1918 aviation moved slowly in Great Britain. Its advancement depended mainly on private enterprise, the Government being slow to recognize the importance of the aeroplane as a weapon or as a means of high-speed transport. Aerial photography—as an important and extensive branch of service work—did not exist. It required the impetus of national danger and the rivalry of an enemy to bring about the rapid development of both photography and aircraft.

When Britain declared war on Germany the increase of personnel of the Royal Flying Corps was begun. Machines for the expanded service were urgently needed and aeronautical firms, then on the point of closing down their works through lack of support, found it necessary to extend their activities; while companies with no experience of aircraft construction were pressed into use under expert technical supervision. By 1918 the Royal Flying Corps had been so widely expanded that it was thought necessary to create a separate Service, and on April 1, the Royal Air Force was established.

All this while, of course, aircraft design was being rapidly improved and aerial photography became more and more a specialized business, necessarily directed in war channels. What had been practically non-existent—the combination of aeroplane and camera—suddenly emerged as a highly specialized science which required

considerable application, knowledge and practice from those engaged in its development.

PROGRESS OF CAMERA AND MACHINE

The progress of the heavier-than-air machine and the camera, side by side as it were, is interesting. In the early stages of the war the aeroplane was used mainly for offensive and defensive purposes, and to assist the land and sea services by carrying out observation work, the observer making his reconnaissance by ordinary visual methods. His duty was to act as an aerial detective, making notes of the movements of troops and recording on maps the position of trenches, ammunition dumps and the like. He had to rely chiefly upon his visual observations and an intelligence which would grow keener only by continued experience as an observer. An intuitive facility for grasping and understanding the significance of small details was, of course, an undeniably important gift, but it could not be depended upon in every single observer who took the air for reconnaissance work. The human liability to err rendered visual methods of observation open to certain strong objections, and it was with some relief that many welcomed the mechanical precision of the camera.

Exactly how the aerial camera was first introduced for military and naval reconnaissance is a speculative problem. The use of many notable inventions has been ascribed to accident, and applied photography from the air is no exception. It has been reported, whether accurately or not we cannot say, that in the early days of the war, a private soldier managed to obtain a flight in a battle 'plane over the front. He carried, against the rules, a small camera with him, and photographed whatever happened to interest him during the journey. When the machine returned it was discovered that the passenger had carried a camera. The films were accordingly confiscated and developed. To the astonishment of the authorities the films provided accurate and detailed information which the trained eyes of an observer had previously missed. The private soldier had unwittingly provided a permanent record which could be studied and interpreted by many eyes and many minds. Another report credits Germany with the introduction of aerial photography

in warfare. Although the British were carrying out a few experiments, it was not until a camera on a captured enemy craft revealed vital military information that a thorough investigation of the merits of aerial photography was made. One of the co-authors of this book remembers a number of German flying pupils who came to England before the war and who were discovered to have carried cameras during their advanced practice flights. It is his theory that the system of sending German pupils to England to learn to fly was a clever espionage trick, showing much forethought and perhaps a considerable knowledge of aerial photography.

If all stories have some foundation in fact it is probable that the soldier incident described above is more than an allegory. Be that as it may, the time came when it was realized that the record of an aerial camera was likely to embrace more than that of the ordinary visual observer.

THE FIRST PRACTICAL CAMERA

Operations were at first undertaken with ordinary types of ground cameras, mostly of the Press variety, but by the end of 1915 cameras designed expressly for aerial work were put into production. Lieut.-Colonel J. T. C. Moore Brabazon, M.C., who was later the chief of the Photographic section of the Royal Air Force, designed and produced—in conjunction with Messrs. Thornton Pickard, Ltd.—the first practical camera for aerial operations. This was later improved upon, and the results obtained with the new design were responsible for convincing the military authorities of the value and importance of photographic reconnaissance. Large contracts were placed with many manufacturers. Incidentally an impetus was given to creative genius to produce rapid plates and films and suitable lenses, for improvement in the actual mechanics of the camera was not the sole difficulty that had to be faced. As will be shown in another chapter, aerial photography is a combination of many sciences and the camera must be "fed" with the best possible material.

As activity in the air increased and danger pressed upon the country the photographic sections of the Navy and Army grew enormously until the R.A.F. establishment alone was producing an

average of one thousand exposures and prints daily. The camera automatically came to be recognized as the " eye " of the Forces, and every belligerent country realized its indispensability. Without it the fortunes of war might have gone very differently—how differently it is not within human power to say. That its importance was finally considered vital resulted in applied aerial photography becoming an established feature of war and, nowadays, a rapidly expanding industry of peace. It is likely to become one of the chief mainstays of Civil Aviation in all countries.

The introduction of the aerial photograph completely changed the tactics of war. So much information that would otherwise have been concealed from the enemy was revealed by the all-seeing lens. Camouflage had to be introduced where hitherto it had been unnecessary. Not only was it found expedient to make use of camouflage to deceive the human eye; it was also found necessary to reconsider the whole problem of camouflage with a view to deceiving something more accurate and more permanent than visual observation; and even though the camouflage experts gave of their best their efforts proved almost futile, for the precision of the lens could not easily be countered.

It was discovered possible to discern—by means of the air camera—indications of even *probable* movements on the part of the enemy. The disclosure of variable amounts of rolling stock at important railheads, the increase or decrease of ammunition at dumps, new railways in process of construction, the increase in the number of Red Cross establishments—these and other phenomena recorded on the finished prints were sufficient clues upon which to form obvious deductions concerning the enemy's approaching activities.

VALUE IN WARFARE

Maps were kept up to date by repeated photographic surveys, and by comparing exposures made at different intervals, the amount of work done by the enemy was clearly shown in spite of the improved methods of camouflage. No matter how carefully machine-gun emplacements may have been concealed, their position was often betrayed by the disclosure of foot tracks made over-night to and from

munition dumps. Dummy trenches and other appurtenances of warfare were detected easily enough, for the absence of shadow on the completed prints was sufficient to rouse and to justify suspicion. Bearing in mind the movable nature of shadow it was practically impossible to fake anything to take its place.

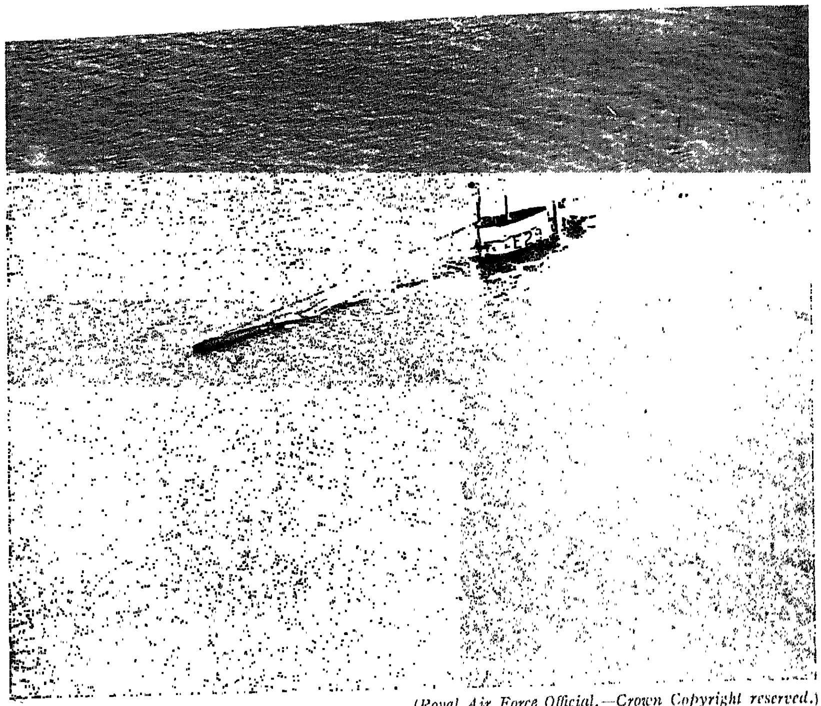
The secret movements of troops under cover of darkness was recorded by the aerial photograph as soon as it was light enough for the operators to work. The burden of large numbers of men, no matter how stealthily they moved, left its mark upon the earth's surface, tracks being left on arable and grass-land alike. Careful study would reveal whether mounted or unmounted troops had been moved, and in what formation and to what extent.

The interpretation of aerial photographs was, of course, a real problem and one of vast importance. It meant considerable training of men of high intelligence, and at first much of the training depended upon guess-work as well as deduction, for it was only by an ever-increasing experience that the interpreters could learn the significance of new details and classify their deductions until they had a reliable photographic key or code upon which to work and through which to teach new recruits. The smallest detail had to be accounted for in terms of military importance. Nothing was too slight to escape the attention of those whose difficult task it was to provide rational explanations of the photographs. Everything revealed in an aerial photograph means something, and in warfare margins of error are neither safe nor officially acknowledged. Accuracy alone was not enough. Speed in copying the photographs and supplying them to Headquarters with correct interpretations was also essential for the successful conduct of operations.

No offensive or defensive operation was undertaken without a preliminary consultation of the photographic records made from the air. Hence the continuous struggle for aerial supremacy. By gaining command of the air and thus more or less complete freedom to undertake photographic operations the Allies had the activities of the enemy and, as we have said, possible future activities (as well as past and present), laid before them like an open book.

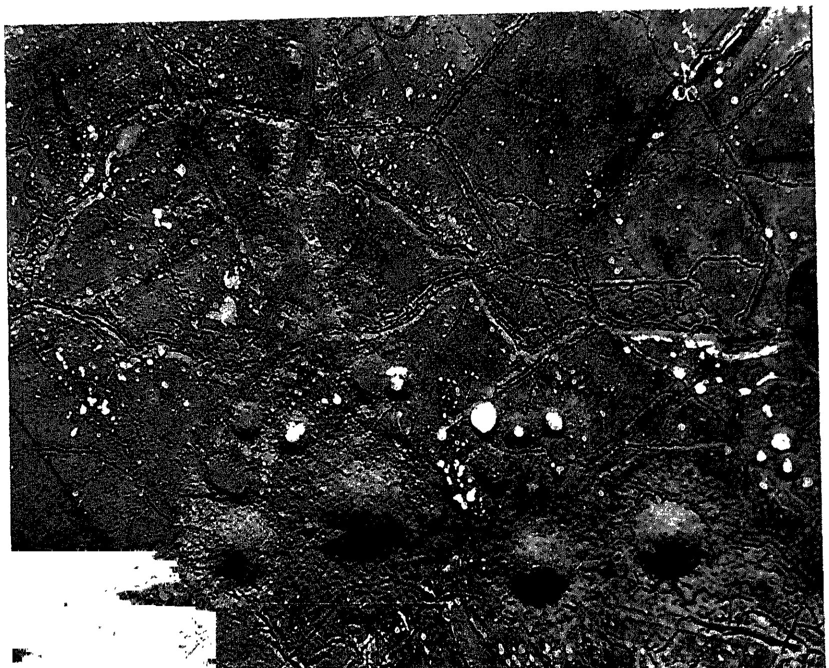
While the military operations were undoubtedly more comprehensive and perhaps more valuable than those of the Navy so far as

PLATE No. 1.



(*Royal Air Force Official.—Crown Copyright reserved.*)

FIG. 2. A BRITISH SUBMARINE PARTIALLY SUBMERGED.



(*Royal Air Force Official.—Crown Copyright reserved.*)

FIG. 3. SHELLED GROUND AND TRENCHES.

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aerial photography is concerned, the camera was not without its uses at sea. Mine-fields were frequently located. Damaged and sunken submarines were "spotted" by means of the oil patches which showed clearly on the prints; and a full photographic record of sea transport within and outside the controlled channels was kept. What were known as "swirls" on the surface of the sea were of great interest. They denoted in some instances submerged objects, more often than not of naval importance, and while such a phenomenon was not always visible to the naked eye it was invariably traced by the camera. When mines were laid in too shallow water a series of swirls would be set up, and the interpreter of the photograph would at once recognize these swirls for their true value.

In addition, much coastal photographic work was done by aerial photographers co-operating with the Navy, it being part of their duty to photograph the effects of gunfire and bomb-dropping inland, and to detect the extent and significance of the enemy's coastal defences. (Figs. 2 and 3.)

CONDITIONS OF SERVICE

The conditions under which photographers had to work in the services were naturally enough severe. The observer or gun-layer, as the operator was officially designated, was first put through a course of training in elementary photography and was instructed in armament, navigation, wireless and the spotting of gun-fire. His training, therefore, was necessarily brief but intensive; and in view of the urgent need of expanding the photographic section it was desirable that the camera should be very simple in operation—fool-proof and automatic in action. Photographers, the majority of whom were complete novices, had always to be alert, watching for the enemy and ever ready to engage in aerial combat; and as the photographer's platform (*i.e.* the aeroplane) was invariably under fire from ground batteries he had but little time for the niceties of professional photography. This being so, and even allowing for the fact that he was eventually supplied with cameras that required very little detailed attention while in flight, it is really astonishing that so many valuable results were obtained amid such arduous conditions.

Very few post-war aeroplanes have been specially designed for

photographic duties, most of the work being carried out in reconditioned war aircraft or ordinary civil transport machines. Compared with the difficulties that faced the war-time photographer, the difficulties that beset the peace-time operator are slight, though they are none the less worthy of the attention of inventors and others who can in any way minimize the handicaps that still remain. And, while we do not hesitate to stress the simplicity of merely manipulating the camera, we should be labouring under a misapprehension if we claimed that the whole science of aerial photography is one that can be covered without wide experience and close attention to technical detail.

Commercial photography from the air, as distinct from war photography—which must always remain in the experimental stage so long as the methods of war change—is now an important feature of industrial life; but, though it has established itself to the point of being of definite utility to the community, there is still much to be accomplished. It will, we venture to say, become an integral part of civil life and will undoubtedly constitute one of the main functions of the aeroplane. In this way it will repay its debt to the navigable platform, for it will provide additional work for aircraft manufacturers and increase the number of pilots, who will have to be specially trained for the work. In succeeding chapters we shall consider in detail the complete science itself, contenting ourselves here with merely a brief survey of how aerial photography came into being. It is, however, essential to realize something of the early development of a comparatively new industry which is likely to have an ever-widening influence among the peoples of the world.

As we have shown, before the air photographer could become an integral part of the social system it was necessary for a navigable platform to be provided. The balloon and the kite are not navigable platforms in the strict sense of the term, although many excellent photographs have been taken by pioneers in balloons and with mechanically operated cameras affixed to kites. The modern aeroplane, however, enables a camera to be navigated to any desired corner of the earth, so long as the airways are politically unobstructed. Physical obstructions do not concern us very much, for the aeroplane of to-day is able to ascend to great altitudes—altitudes, at any rate,

sufficiently high to enable the operators to avoid any exceptional physical contour of the earth. Without the aeroplane there could have been no advancement of aerial photography as we know it to-day ; that is, rapid and continuous photography over extended areas would be impossible if only balloons and kites were available for the work.

Problems caused by speed and vibration have been solved satisfactorily. Airships, of course, did not offer the same problems, but—owing to the high cost of construction, the expense of upkeep and large personnel required for handling purposes—all thought of making general use of the lighter-than-air type of navigable platform had to be abandoned. Airships are, of course, used when the economic factor is not a predominant one. As a perfect type of aircraft for photographic purposes the airship could hardly be excelled, for it offers the greatest amount of space for apparatus, but as the question has to be dealt with from a strictly economical point of view commercially, and as in warfare speed and vulnerability cannot be ignored, the airship is not likely to be used for photography except perhaps in transcontinental explorations. The aeroplane (which term is inclusive of flying boat, land 'plane, and amphibian) is the most perfect camera platform yet devised for aerial operations, and it is to-day being used as such by the geographical expert, the scientist, the surveyor, the archæologist and the geologist, to name but a few of the patrons of the newest branch of photographic science. The chief advantage of the aeroplane is that it is always under human control.

OBLIQUES AND VERTICALS

The field of vision of the human eye from the great altitudes possible to aircraft is considerable if the atmosphere is clear, a continuous panorama being unrolled as the machine proceeds on its journey. From great heights, however, all sense of " relief " is lost, and it becomes impossible to visualize the depths of objects revealed below. The earth takes on a flat plane. The lens of the camera, too, would record a flat plane were it not for the fact that stereoscopic effects can be obtained.

The occupants of an aeroplane view the ground from an oblique

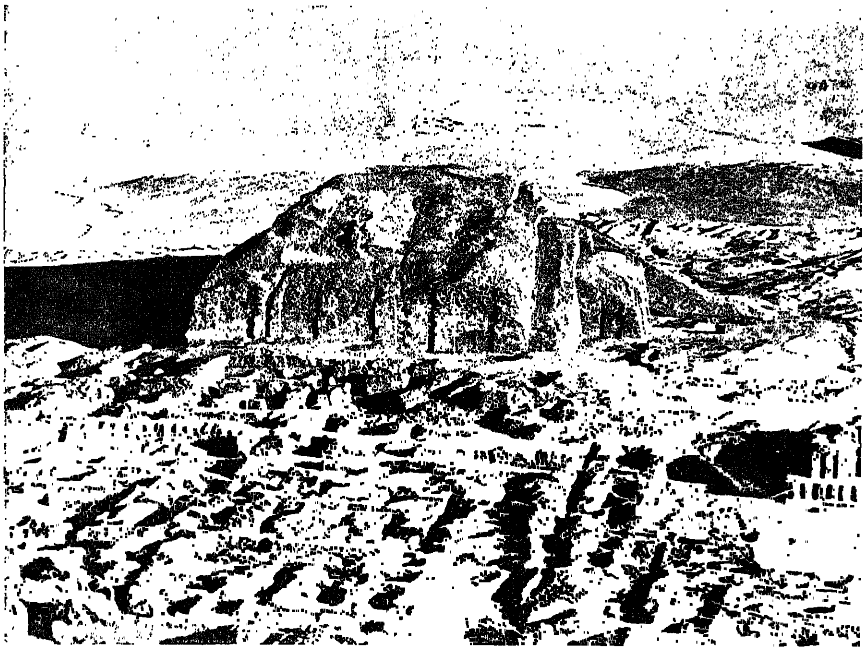
angle, and a camera held or fixed with the lens pointing to the ground from a similar angle produces what are known as oblique photographs. The camera's field of vision is obviously more limited than the field of vision of the human eye, but the view recorded on the plate or film will consist of part of the wide area observed by the occupants of the aircraft. On the other hand, should the occupants of the aeroplane look at the earth through a hole in the base of the machine, the scene presented to them will be in the form of a plan or map. This aspect is a vertical one and illustrates how a camera, pointing directly downwards, is in a position to receive vertical impressions. The two distinct types of photographs are, therefore, the oblique and the vertical. (Figs. 4 and 5.) We will now briefly consider their respective uses, and later deal with them in detail:

Oblique—Throughout this book this term will be used to designate aerial photographs showing pictorial and panoramic views. The photographer can choose his own view-points, and there are hardly any limitations to what he can achieve in this direction. The oblique aspect is more easily interpreted than the vertical, for it produces results less like a map and has the characteristics of a side elevation. Where buildings are featured the elevations are clearly similar to the side elevations revealed in the ordinary photograph, but in addition the tops of structures are shown in perspective, and the complete lay-out inclines slightly towards the observer.

Oblique views provide valuable assistance in the interpretation of vertical exposures. By certain highly specialized and evolved processes, the contour of the ground covered can be fixed from the undulations recorded on oblique photographs. Later we shall have more to say on this new development. Detail in perspective diminishes rapidly, and through displacement caused by the lens the detail to the left and right of the picture becomes distorted, and it is therefore not practicable to overlap and to join up consecutive views taken from an oblique angle.

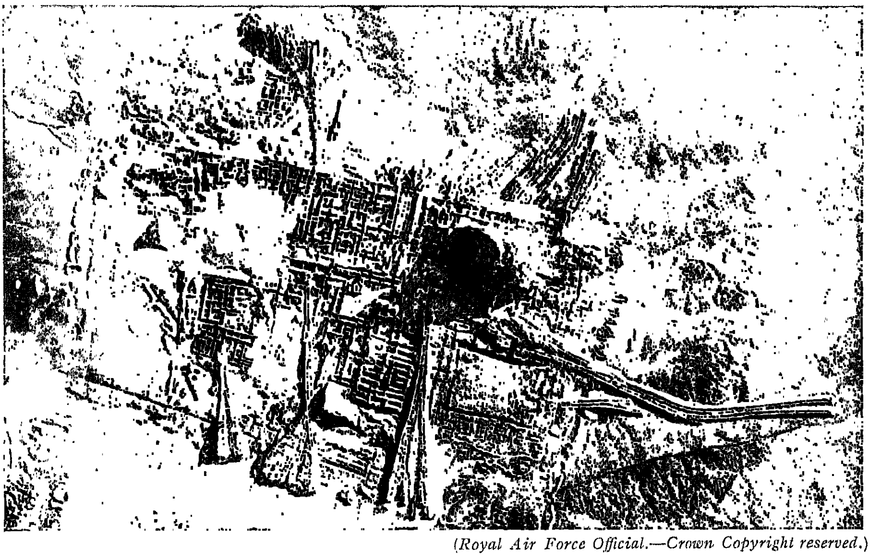
Vertical—This type of photograph produces plan records of the earth's surface. Unlike oblique pictures, the verticals may

PLATE No. 2.



(*Royal Air Force Official.—Crown Copyright reserved.*)

FIG. 4. THE OBLIQUE: UR OF THE CHALDEES, SHOWING THE GREAT MOUND KNOWN AS THE ZIGGURAT.



(*Royal Air Force Official.—Crown Copyright reserved.*)

FIG 5. THE VERTICAL: A PHOTO PLAN OF THE EXCAVATIONS OF UR.

To face page 12.

be taken consecutively and overlapped, so that a complete photographic map and survey of any desired area may be made. The vertical is preferable where accurate location of objects is desired, and it is distinguished by an equality of detail over extensive areas. Its main use is in the making of maps or, more accurately, illustrations that serve as such. The untrained mind can divine more information from a vertical photograph than the trained mind can from an ordinary topographic map, although we cannot claim for the aerial view extreme accuracy until it has been corrected for distortion caused by tilt, and adjusted to a system of controls supplied by a ground surveyor. It is possible that the time may come when for cadastral and ordnance purposes the aerial photographic survey will be accepted as a map after the customary references already provided by drawn maps have been added.

Whereas trees and the like are illustrated on the drawn map by cadastral signs presented in positions that call for the use of imagination or reference to the key in the body of the map, vertical aerial photographs reveal the formation, lay-out and even nature of forestry and other terrestrial marks, thus giving a true topographical impression of the earth's surface.

The ordinary plan of a town provides but the outline of public ways and buildings. The photographic map of a town provides this—and something more. Added to the outline of streets and highways are many virtues the value of which cannot be overestimated. For example, when the eye is trained to the photographic view it is possible to differentiate the various kinds of buildings alongside the thoroughfares and even to gain some idea of the nature of the property. Open spaces are recorded in detail, and waterways and coastlines revealed by the aerial photograph do not lie. It will be seen, therefore, that the vertical photographic map has many advantages over the drawn map, once the former has been corrected and adjusted, for it is possible to visualize clearly every intimate detail of the surface exposed to the lens.

Both the vertical and the oblique, of course, possess their distinctive virtues, and sometimes, as we have explained, are of service to each other.

PART II

PHOTOGRAPHIC MATERIAL

CHAPTER II

LIGHT VALUES AND ATMOSPHERE

THE farther the operator goes from the earth's surface by means of his navigable platform the less will he be able to detect relief in his objective. The ground below him will appear almost uniformly flat, notwithstanding that it may actually be heavily contoured. Hilly or mountainous country will fail to reveal its true nature if viewed from a high altitude. There are comparatively no strong lights or shadows. It is necessary to bear these facts in mind in relation to the problems of aerial photography.

INTENSITY OF LIGHT

The visibility of objects depends not upon any inherent virtue of their own, apart from bodies which are self-luminous, but upon the amount of light which they reflect. Objects do not, therefore, possess any power of making their own colours, such colours as we see being unabsorbed light scattered and reflected in all directions. Before we can perceive the relative exterior formation of an object, that object must reflect in varying intensity the light rays which it has not absorbed.

As is well known, the intensity of light varies according to time and place. The variation of light intensity exerts the same influence on aerial photography as it does upon ordinary ground photography; as for example, in Southern England there is an increase of illumination at mid-day during June and July of something over forty per cent. compared with mid-day light of November and December.

COLOUR

Although to the naked eye of the operator situated far above the earth there is no stereoscopic effect revealed by the country below, the

photographic plate—or film suitably sensitized—is so made that it will intensify all the available contrast. While the negative will not produce a colour reproduction, it will do the next best thing—*i.e.* distinctly reveal the colours as greys of different tones according to their brightness, or, in other words, according to the quality of their reflected light.

Let us now consider the range of hues presented to the aerial photographer as he flies over a typical part of England. Fields, trees and smaller foliage are chiefly conspicuous. They vary very slightly in colour tone and reflect but little light. The contrast between them, therefore, is not great, and their different classes are not marked with much distinction except in relation to more reflective objects around them. Soil, particularly where by reason of its composition its colour is heightened, affords a greater amount of relief. Roadways, paths and tracks in general, again, according to their composition, have still more reflection and are always clearly revealed by the negative. Waterways give striking light values when reflecting the rays of heavenly bodies, but in certain circumstances—according to the nature of the beds and the extent of the depth—they will afford but little illumination.

The reflection of water, even at night-time, is high when the circumstances are right, and it is only necessary to refer back to the last war to remember how much night flying was made possible by means of the reflected light of waterways. Some waterways stood out almost white on a moonless night, reflecting other light and acting as sign-posts to flying men.

The above bodies may be classified according to the nature of the action they exert on white light, for white light is the basis of all colours, and, as Newton showed, can be decomposed by a prism into the spectral colours of red, orange, yellow, green, blue, indigo and violet—in the order named. Objects other than white will therefore reject one or more of the constituents forming white light.

In dealing with pure water, which transmits all the colours equally well and is accordingly labelled as colourless, we have still to remember that from the photographic view-point it may at times be distinctly coloured. For example, large volumes of water, in small quantities uncoloured, appear blue or green.

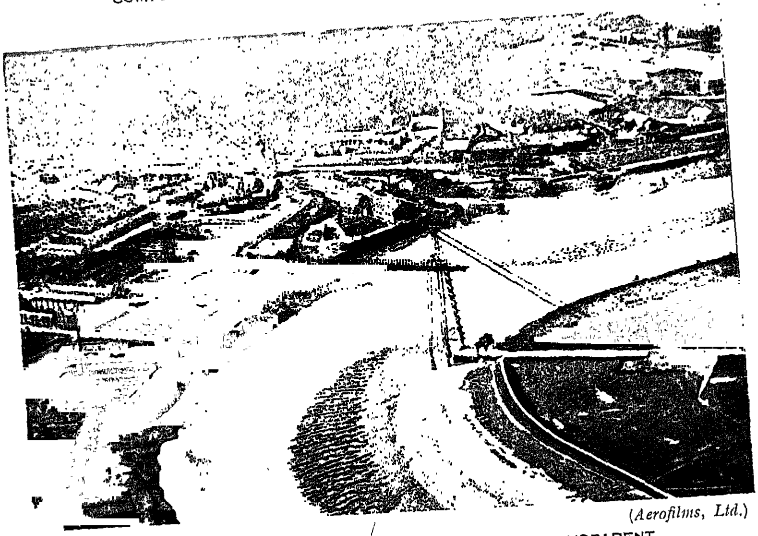
PLATE No. 3.

(*Aerofilms, Ltd.*)

FIG. 6. THE LOSS OF CONTRAST AND DETAIL WILL BE SEEN WHERE SHADOW IS CAST.

(*Aerofilms, Ltd.*)

FIG. 7. THE OUTSKIRTS OF AN INDUSTRIAL CITY. DISTANT DETAIL COMPLETELY OBLITERATED BY SMOKY ATMOSPHERE.



(*Aerofilms, Ltd.*)

FIG. 8. HAZE NEAR THE COAST MORE TRANSPARENT.

To face page 19.

It will be obvious, then, that the different colour light factors must have a marked effect on aerial photography, and that experimental work is still not yet at an end. Incidentally, it is worth mentioning that while many light variations are imperceptible to the human eye, the sensitized film or negative will distinguish them.

The reader will appreciate how important it is to record most precisely the slightest variation of colour. It is, in fact, the predominant feature which gives so much value to the aerial *photographic* survey. It is most important to be able to distinguish the variations in the nature of the soil and vegetation, quite apart from the plotting and architecture of buildings.

ATMOSPHERIC CONDITIONS

Visibility depends upon clarity of the atmosphere, the atmosphere being clear when there is nothing to curtail, subdue or scatter the reflected light. Differences in light quality to the human eye are dependent upon the variation of colour, or power of reflection, and this variation is controlled by the amount of light absorbed by physical objects. Thus, a white chalk cliff, reflecting more light than would a dark-coloured land, will be visible from a greater distance than the darker surface. But, even so, the degree of visibility will vary from day to day, for we must take into account the effect of haze—perhaps one of the greatest bugbears of the photographer, and certainly of the aerial photographer. (Figs. 6, 7 and 8.)

Haze consists of any atmospheric substance which interferes with atmospheric transparency, and it is to the existence of haze that we owe so much experimental work. It has been the main obstacle to more rapid progress and it is the deciding factor controlling the invention and manufacture of suitable material for successful commercial work.

We are all fully aware that when near the horizon the sun often appears golden, or even red, and that this colour effect is due to the sun's rays having to pass through wide layers of atmosphere, the atmosphere acting as a light filter and cutting out most of the violet and blue rays—the rays to which the photographic plate is predominantly sensitive. The more highly sensitive the plate is to orange and red

rays and the less sensitive to ultra-violet, the less will it be affected by wide layers of atmosphere. Hence the tendency of manufacturers in all countries to produce a plate highly sensitive to orange and red.

Aerial haze is a constant menace to photography from a distance, more particularly in oblique views. On an ordinary plate it gives rise to a flat result and absence of detail. In some instances there will be no photographic impression at all, normal contrast or differences in brightness being insufficiently marked, and the atmosphere being heavily laden with offending obstacles which are not necessarily visible to the human eye. The composition of haze consists of dust and water in suspension and, in a small degree, of air molecules themselves. When sufficiently pronounced it is visible as a bluish-white mist, varying considerably in intensity, the extent of the deterioration of the transparency of the surface layers of atmosphere depending upon local circumstances as well as upon general climatic conditions.

While the words mist and haze are generally used to mean the same thing, strictly speaking there is a difference between them, though the aerial photographer may well look upon either as an enemy of no mean importance. Mist consists of water particles floating near the earth's surface and occurs only when the air is partly or entirely saturated, while haze may be defined as dry air obscured by solid particles. For our purposes, however, it is sufficient to use the word haze to cover any and every form of atmospheric obscuration, and we shall continue to use this term.

The causation of haze is explained in many ways. The action of the sun upon the earth's surface will produce obscuration, as will the descent of a cloud of water particles in massed formation, and at all times there will be a considerable degree of variation in the density. For example, when drifting over towns—and especially industrial districts—haze will collect particles of soot, dust and the like, until in some instances it will develop into a thick fog. Industrial areas invariably have a constant haze.

Usually it hangs or drifts in layers, sometimes at the earth's surface, but oftener at high altitudes, and frequently there are several distinct layers at different heights. Not being a transparent medium, it interferes with the clarity, contrast and definition of a photograph,

and from a height of, say, 10,000 feet it is often impossible to secure any view of the ground at all.

THE EFFECT OF HAZE

Reflecting, as it does, a strong actinic light back into the camera lens, it superimposes a uniform illumination over the object being photographed. This has the effect of causing a superficial exposure of the plate, thus masking the main image, its radiation being greater than that of the reflected light from the ground. The high lights of the subject are then secondary and cannot be properly recorded, the contrasts in the objective being very much reduced. The reflected light from haze is often deceptive and is not always noticeable to the photographer until the plate is developed.

Haze also results in the absorption of certain colours, scattering the violet and blue of the spectrum, thus making them predominant, and scattering the green, yellow and red to a lesser degree. It is therefore selective in its veiling. This effect causes a serious loss of detail.

The elimination of haze, however, is made possible by the adoption of colour filters and by colour sensitized plates or films—a subject which we shall cover fully later on. By use of these additions to photographic material the photographer is able to secure a truthful tone reproduction of the varying colour values of his subject. The density of haze over and surrounding industrial districts, however, is sometimes so great that it is almost impossible to penetrate it; parts of such cities as Manchester and London can be photographed obliquely from the air on an average of only one day a month.

DETERMINATION OF HAZE DISTRIBUTION

In the monograph on Aerial Haze issued by the Research Laboratory of the Eastman Kodak Co. is the following enlightening account of valuable experiments conducted at Langley Field, Hamblon, Va., to determine the distribution, the quantity and the quality of haze. We are indebted to Messrs. Eastman Kodak for permission to reproduce the results of their pioneer experiments.

"The determination of the distribution, the quantity and the quality of haze is possible only by observations from aeroplanes at various altitudes and under different weather conditions, and, since these important factors must be considered from a photographic view-point, photographic methods are employed. Therefore it is necessary to frame a definition of haze in terms of its measurable effects upon the developed photographic material. This definition is based upon the two obvious effects. The suspended materials in the atmosphere scatter sunlight, and hence send back light to the camera, which adds to the exposure creating an image of the subject: these materials also subtract somewhat from the light reflected upward from the ground. Although these tendencies work in opposite directions in their effects upon the exposure which the photographic plate receives, there is no reason for assuming that they exactly counteract one another. The absorption or subtractive effect of the haze is concerned with much less light and is no doubt of less importance.

"Assume that the subject to be photographed contains objects which are white, grey and black. Let E_w, E_g, and E_b, respectively, represent exposure values, in candle-meter seconds if convenient, due to these objects. When the camera is near the ground, no haze effect except, of course, the general decrease in ground illumination, is involved. At any altitude A let the exposure due to the light from the haze be e and let h' be the ratio of e to E_w so that

$$h' = \frac{e}{E_w} \quad \text{or} \quad e = \frac{h'}{E_w}.$$

Therefore the total exposure giving rise to the image of the white portion of the subject will be

$$E_w\ (1-a) + h'E_w,$$

where $(1-a)$ represents the absorption or subtractive effect of the haze. Similarly, for the black portion of the subject the total exposure is $E_b\ (1-a) + h'E_w$, and for the grey $E_g\ (1-a) + h'E_w$. This is true since the relative amounts subtracted and the absolute exposure added

are identical for the white, grey and black portions of the subject. Therefore, if on a photographic material, exposed at any altitude, the ratio of exposures on the white and black objects respectively is K, then

$$\frac{E_w\ (1-a) + h'E_w}{E_b\ (1-a) + h'E_w} = K\ ;$$

or, dividing both numerator and denominator by $E_w\ (1-a)$,

$$\frac{1 + \dfrac{h'}{(1-a)}}{\dfrac{E_b}{E_w} + \dfrac{h'}{(1-a)}} = K.$$

Now let $\dfrac{h'}{(1-a)} = h$, and further let $\dfrac{E_w}{E_b} = C$, which is measured from near the ground, say at an altitude of 500 feet.

Then
$$\frac{1+h}{\dfrac{1}{C}+h} = K,$$

solving for h
$$\frac{C-K}{C\ (K-1)} = h,$$

h is the haze effect expressed in such terms as are readily obtainable by photographic methods. The evaluation of C and K from plates exposed from various altitudes will be considered later. However, it may be remarked here that the fraction $\dfrac{h'\ E_w}{E_w\ (1-a)}$ is the ratio of the exposure due to the haze to the exposure given through the haze by the white portion of the subject; and this ratio is obviously equal to h, the haze effect. It is also evident that this evaluation of haze is independent of the actual brightness values—a fact which will be discussed later.

EXPERIMENTAL METHODS

"The method consisted primarily in photographing three test objects—a black, a white and a grey canvas, each 60 × 60 feet, of known reflecting power, spread in order upon level ground (Fig. 9). These canvases were photographically non-selective in reflection—a necessary condition, since the quality of haze was one of the factors to be determined. The contrast between the white and the black canvas was approximately 1 to 8. The reflecting power of the three canvases was measured both visually and photographically, with the results given in the following table :

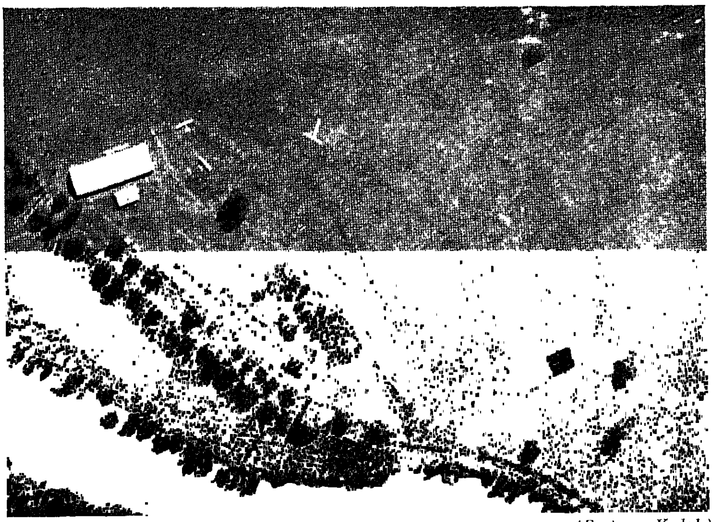
TABLE I.

Canvas.	*Reflecting Power.*	
	Photographic.	Visual.
White	56·0	64·8
Grey	17·5	20·1
Black	6·7	7·5

"The cameras used were a four-lens type especially designed for this work (Fig. 10). Four 1C Tessar lenses, each of ten-inch focal length, are placed at equidistant intervals in the lens board. The plate-holder (Fig. 11) carries four 4 × 5 inch plates and is fitted with a notched template to make it possible to determine the position of a plate in the camera. Provision is made in each lens barrel for the insertion of colour filters. The camera thus served as a photographic spectrometer, since the filters chosen were of such cut as to divide the spectrum into sharp intervals of known area.

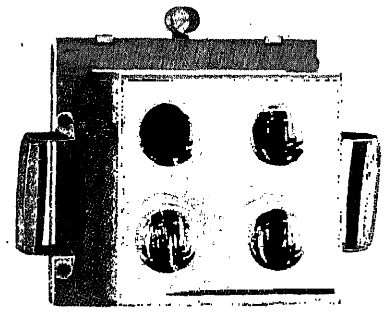
"In order to make the exposures received by the four plates as nearly equal as possible, the camera was calibrated. The stop or diaphragm values of the lenses, the speed of the shutter and the relative total transmissions of the filters used were considered. The times of exposure for the four different slit widths and the six tension values of the focal plane shutter were determined by means of a shutter tester, which depended upon the operation of a tuning-fork of known frequency. The values of exposure times obtained were plotted as functions of the distances moved by the slit, and the time value which corresponded

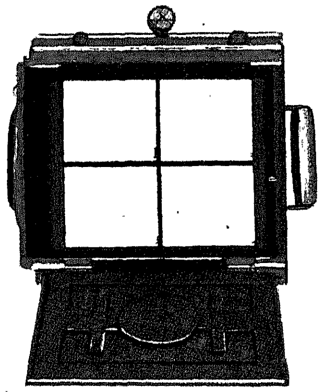
PLATE No. 4.



(*Eastman Kodak.*)

FIG. 9. TEST OBJECTS ON LANGLEY FIELD, HAMBLON, VA., USED FOR EASTMAN KODAK "HAZE" EXPERIMENTS.





(*Eastman Kodak.*)

FIG. 10. FOUR LENS TYPE CAMERA. FIG. 11. CARRIER FOR FOUR PLATES.

to the value at the centre of the plates was selected for use. The filter factors, which differed for the various types of photographic materials used, were defined as the ratio of exposures through the colour filter and through a plain gelatine or dummy filter when both exposures produced a density of unity, the plates having been developed together for a time that gave a y value of unity on the plate exposed through the dummy filter. These factors were obtained by means of a non-intermittent sensitometer, using identical exposures on the two plates by adjustment of the distance from the source of light to the plate and the aperture over the source; so that when these factors of distance and aperture were considered, the two characteristic curves intersected at a density of unity when the y of the plate exposed through the dummy filter was also unity. In this way it was determined, for example, that the filter factor for the Wratton and Wainwright No. 12 filter is 6·4 for a particular panchromatic plate, while for an ortho-chromatic plate the factor for the same filter is 8·5. Suppose, now, that the motion of the focal plane shutter is from lens A to lens B, and that A has a blue filter, B a dummy filter; and, further, that it has been found that for the desired slit and tension, the ratio of exposure times of A to that of B is as 3 to 2. The plate to be used is ortho-chromatic. Because of the motion of the aeroplane during the taking of the pictures, the shortest adequate time is to be used, and the stop of lens A is at f/4·5. The exposure at B must be 1/8·5 of that at A. Thus $2/3 \times 1/X = 1/8{\cdot}5$ and X will represent the fractional reduction to be produced by the stop. Therefore the stop of lens B is set at f/10·7. With the stop values thus set for each filter to be used, the adjustment was checked by photographing a non-selective white diffusing surface in sunlight. Equal densities under the conditions of calibration as regards development were thus produced. The latitude of the material ordinarily covers small departures from precise equality in the resulting exposures.

"The establishment of a numerical relation between density and exposure by interpolation on a scale of densities produced by known exposures was provided for by an intensity scale adaptable to field use. In this case the intensity scale method consisted of printing a series of areas of known transmission and selectivity on the material used to photograph the test objects. One of the lenses was replaced by a

glass plate supplied by the manufacturer of the lens and intended to duplicate it in absorption and reflection. In the corresponding section of the plate-holder a 4 × 5 inch tablet was placed having five sensitometric strips of ten sections each, of which the transmissions were known. Except for these strips the tablet was opaque. Colour screens were placed between each strip and the glass cover plate, the heaviest filter corresponding in position to the slowest shutter speed. The photographic material placed over the tablet could receive light only through the filters and accompanying sections. The exposure was made over the white canvas. The filters in the tablet were the same as those used in the three other lenses of the camera.

"In the construction of this tablet it was desirable to have the log transmissions of the successive steps in any strip in arithmetical progression. These log transmissions differ by a constant from the log exposure given through them to the photographic plate, and when the characteristic curves for the observations are to be plotted, it is undesirable that the log exposure values should be unevenly grouped along the axis. In order that these log transmissions of successive steps on the strip should be uniformly separated, the corresponding exposures were calculated, as follows: In the co-ordinate system given in Fig. 12 the negative X axis represents the values of log transmissions of the tablet uniformly spaced. Since density equals log opacity

$$\left(\mathit{log}\ \frac{1}{\mathit{transmission}}\ \text{or}\ -\mathit{log\ transmission}\right),$$

the same values and spaces transferred to the positive Y axis represent densities of the areas of the tablet. In the first quadrant is given the characteristic curve of the plate and the time of development used, which plate is to be used to make the tablet. Now, if the equally spaced points along the positive Y axis are transferred to the positive X axis, the new points will represent the various values of log exposure to be given in making the tablet. These points are again transferred to the negative Y axis by means of a logarithmic curve and the ordinates so determined are the exposure values which should be given the plate of which the characteristic curve is shown in the first quadrant, in order that the tablet have the transmissions desired. The determination

of these values gives the exposure times to be used in the preparation of the tablets in the non-intermittent sensitometer. It appears, for example, that the first, fourth, seventh, and tenth steps are to be produced by exposures proportional to 0·16, 0·31, 0·58, and 1·2 respectively, or equal to these numbers in the units represented along the positive X axis. Many tablets were made in this way, with various highest density values. This was to compensate for the low total transmission values of the filters to be placed over the tablets.

"For example, in order to produce a good H and D curve by the same time of exposure through the tablets, over which different colour screens were used, it was necessary to place under the heaviest filter a strip of low densities, and under the lighter filters strips of higher densities. The tablets were developed in an Elon developer so as to produce a deposit of as little selectivity as possible. These tablets formed the intensity scale sensitometers used to interpret the air data. Exposures were made through the tablets (over which suitable colour screens were placed as described) by light of the same quality as that by which the photograph was taken. Thus the density of any image in the aerial photograph is readily referable to the characteristic curve of the plate on which it is taken, and the ratio of exposure values derived. From these the value of the haze effect, h, is determined.

"In this method of field sensitometry, then, it is possible to make exposures from a plane in the air at the time when the pictures of the test objects are taken. This could be done in the fourth section of the four-lens camera, the three remaining sections giving photographs of the test objects. This, however, makes the time of exposure for the sensitometric strip and for the image plates equal. As the altitude increases, the light through the plates or tablets comes from a wider and wider extent of territory. The region included at Langley Field would be at first only grassy fields, then some buildings, some woods, and finally areas of water would be included. Because of this fact the quality of the light would vary with altitude, and inasmuch as such variation directly influences the relation between density and exposure, it is to be avoided. Even in the method finally adopted, where the exposures were made directly over the white canvas test object, the camera being held by an observer on the ground, some discrepancy is possible. The light by which the picture is taken from

an altitude of 10,000 feet, for instance, might not be the same as that near the ground even when the picture and the sensitometric strip are made at the same time. To determine the effect of this difference upon the sensibility of the plate—that is, in technical terms, the effect of altitude on *y*—flights over a uniform background, *e g.* water, were made."

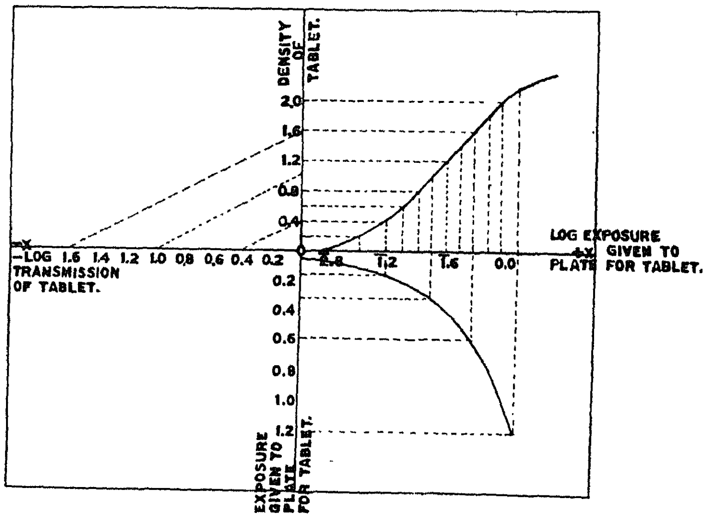


Fig. 12.

CHAPTER III

PLATES AND FILMS

THE progress made in photography from the air during the last few years has been in a large measure assisted by improvements in the materials employed. It can be readily understood that the very rapid exposures which it is necessary to give during flight, especially with long focus lenses, make the use of plates of the highest rapidity absolutely imperative. When the exposures are made from a great height the detail of the land below is very small and the plates must, therefore, be so manufactured that they reciprocate the power of the modern lens to supply the finest definition. The sensitiveness of the plate to colour also plays a not inconsiderable part in the rendering of detail and in other directions upon which we shall later comment.

COMPARISONS

For aerial survey work, which is now being undertaken in different parts of the world, films are being used in preference to plates. They are light (their weight is practically neglible) and for this reason greater bulk can be carried. In survey operations it is desirable to take as many photographs as possible during one flight—partly for economic reasons and partly because it enables all the exposures to be made in the same climatic conditions. At the same time, plates still possess many advantages, for they afford a more permanent record, are easier to handle, and stand rougher usage, and, what is most important, have a much finer grain than films. With films the operator's choice is limited to roll films, for cut films involve the additional disadvantages of plates. We may sum up briefly as follows :

PLATES :—Chief advantage is rigidity. The image is solidly bound to a rigid support, and can be developed and dried without any intricate apparatus.

ROLL FILMS :—Chief advantage is lightness and simplicity of feeding. The early disadvantage of speed, contrast, and shrinkage has now been practically overcome, as has the problem of ensuring the flatness of the film in the focal plane. Unfortunately, the film cannot at present be made so sensitive to *colour* as the plate.

Although but a short time ago the speed, contrast and colour sensitiveness of the film were inferior to the marked virtues of the plate, the emulsion and film base now compare favourably with the plate, and for certain classes of work the film is the better medium. Of course, extra precautions have to be taken against the effect of heat upon films in tropical climates, but storage and development difficulties are overcome by the introduction of ice.

It is maintained by a few experts that the film will never be sufficiently reliable for accurate large scale aerial survey owing to expansion and contraction causing a variation of the scale, and to the loss of detail through coarse grain accentuated by enlargement which is seldom extended above two ratios. For strict accuracy such critics advocate the use of the plate. By a process of averaging the slight discrepancies of scale on each film, it is, however, generally claimed that accuracy sufficiently reliable for all practical purposes of mapping can be secured with the film.

In America and on the Continent of Europe plates are used very little, but in Britain—with its less brilliant light—they are invariably used except during the Spring and Summer months when aerial surveyors adopt the roll film.

At times films were subject to the static markings (somewhat like the branches of a tree in shape) caused by electric discharges affecting the emulsion, but there is now little risk of that as friction in the modern cameras has been reduced to a minimum. Some manufacturers treat the non-sensitized side of the film with a gelatine coating which dissolves on development. These markings can, of course, be introduced by the manufacturer—perhaps through cutting the film at too great a speed ; or by the photographer, through careless handling while loading into the magazine or winding on the development apparatus after exposure. Dry atmosphere is largely responsible. (Fig. 13, facing p. 32.)

Plates, unlike films, are not affected by irregular shrinkage. In

spite of this, we are of the opinion that for certain branches of aerial work the film is preferable to the plate. Films can be carried in rolls sufficient for a hundred exposures or more, such exposures being cured in definite sequence, developed and sometimes printed as a unit.

For oblique work, especially of a pictorial nature necessitating much handling for printing and enlarging, the plate is preferable though in America it is seldom used. For exhibition purposes enlargements are frequently prepared up to 36 by 24 inches (and sometimes even larger) from a 5 by 4 inch negative. Thus, any grain to be found in film would prove objectionable and perhaps fatal to the enlargement. Only a well sensitized and properly developed plate will stand such magnification, for there are fewer flaws to enlarge. But as for aerial survey mapping an enlargement beyond three ratios is undesirable films can accordingly be used for this work with success.

Although in some instances only plates will be referred to in this chapter, our references may apply equally to films.

SIZE AND SHAPE

In ordinary ground operations films and plates up to 15 by 12 inches are used, but for aerial work the sizes generally adopted are as follows :—5 by 4 inches, 18 by 13 cm., 8½ by 7½ inches, 9 by 7½ inches. Small plates mean easy handling. Further, they allow of a camera and general equipment which are compact —a necessity for work in the air. The size 5 by 4 inches was generally adopted in this country for vertical views during the last war, and for oblique work it is still used to some extent, but for modern surveying the common practice is to use films of sizes near to 9 by 7 inches. There is a tendency to favour for the image a square size for vertical work.

The covering radius of the lenses also determines the size of the plates and, of course, of the camera—whether for oblique or for vertical work. To secure detail, pictorially, for obliques of a Commercial nature, an 8 inch or 10 inch focus is desirable. When it is necessary to photograph specific buildings in large towns, it is essential to use a 20 inch lens as the flying height is restricted according to the Aerial Navigation laws. But for reconnaissance work to cover a large area,

a wide angle lens of, say, 6 inch focus would be used. In the case of aerial surveying, everything depends on the scale required. For small scale work 6 inch would be applicable, whereas a 20 inch or longer focus lens is used for large scale work. The sizes of plates and films already mentioned are used for lenses of the focal lengths as above. The full length of a rectangular plate may be utilized so long as the covering radius of the lens does not produce distortion.

The Messters automatic roll film camera for surveying uses a very long and narrow section of film, size, 6 by 24 cm. The British " Eagle " survey camera adopts a 9 by $7\frac{1}{2}$ inch film, with a 7 by 7 inch picture. On the $1\frac{1}{2}$ inches of margin, details as to each exposure etc., are automatically recorded. (Fig. 14.)

SUITABLE FILMS AND PLATES

The following is a list of some of the recommended plates and films suitable for aerial photography:

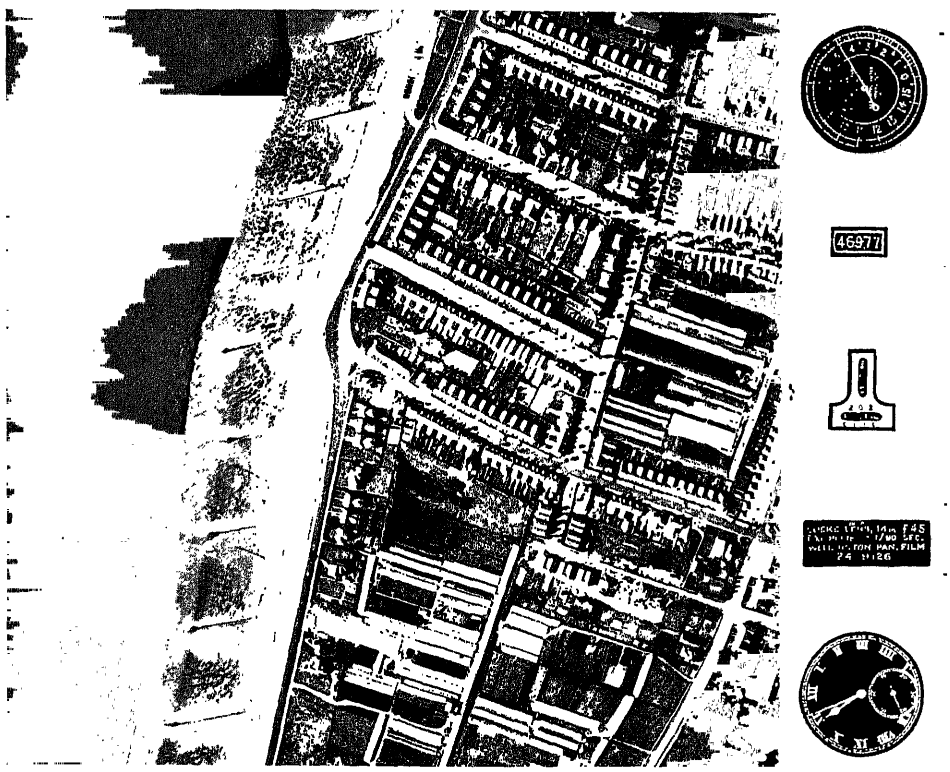
Manufacturers.	*Name.*	*Plates or Films.*
Ilford, Ltd.	" Special Rapid " Panchromatic	Plates
Imperial Dry Plate Co., Ltd.	Panchromatic " B "	Plates
Wellington & Wards, Ltd.	" Spectrum " Panchromatic	Plates
Wellington & Wards, Ltd.	Panchromatic Film	Film
Eastman Kodak, Ltd.	" Aero " Panchromatic	Film

EMULSIONS

The best and most efficient photographic plate or film emulsion is the panchromatic; it has a pronounced colour sensitiveness and affords good contrast and definition. Manufacturers have in recent years produced a very fast emulsion which does not, as might be expected, show any diminution of contrast or increase of grain. This increase of speed, combined with quality, has greatly advanced the commercial utility of aerial photography, for it enables exposures to be made successfully during some of the dull winter months which

PLATE No. 5.

FIG. 13. STATIC MARKINGS.



(*Royal Air Force Official.—Copyright reserved.*)

FIG. 14. A 9 IN. X $7\frac{1}{2}$ IN. FILM WITH A 7 IN. X 7 IN. PICTURE AND $1\frac{1}{2}$ IN. MARGIN, FOR RECORDING DATA AS OBTAINED WITH THE "EAGLE" CAMERA.

To face page 32.

otherwise would be unproductive. In conjunction with such plates filters are used. This subject is dealt with later. In dealing with the questions of grain, speed and contrast of emulsions, the usual photographic theory and formulæ are not herein covered but the information may be found in most text books on the subject. What we are mainly concerned with is the solution of problems that apply specially to photography from the air, and except where otherwise shown our statements will refer to colour sensitized material.

The size of the grain of an aerial negative is of the utmost importance as already emphasized. As better results are obtainable by the use of a small plate or film the grain should be as fine as possible. For oblique work, in which, as we have shown, enlargements to several ratios are often made, it is more satisfactory to use a plate, glass affording a slightly finer grain than film. The size of the silver bromide grains in the sensitive emulsion has much to do with the behaviour of the plate when undergoing development. With a plate of poor grain quality or under unfavourable developing conditions neighbouring grains will sometimes expand, joining together and forming coarser grains. This may cause lack of definition and will sometimes produce flatter results when enlargements are made.

Figs. 15 and 16, facing p. 34, show the grains before and after development in a high grade panchromatic plate suitable for aerial photography. It will be seen that before exposure the grains are flat crystals of silver bromide of triangular or hexagonal shape, while during development their contour becomes blurred. But in a good plate or film the developed grain occupies no more, or very little more space than the crystal from which it is reduced.

CONTRAST

An aerial plate or film must necessarily be capable of providing good contrast in order to differentiate between distant objects of slightly varying reflecting powers. In an oblique photograph a building may appear no larger than $\frac{1}{16}$ of an inch on the negative, but a good film or plate will clearly define the angles of the object and difference between the walls and roof.

By means of a diagram (Fig. 17) this question of contrast may

be more easily understood. We will represent the amount of density in one negative by AC, and in another by BC, for the same exposure OC; and by PR and QR respectively for a shorter exposure, OR. It will be obvious that while the ratio of densities for each exposure are the same, the apparent contrast and certainly the printing contrast are much greater in the plate represented by OR.

In testing emulsions successive narrow strips of a plate are exposed to a constant source of light, each strip receiving twice the exposure of its predecessor. The first strip, for example, would receive an exposure of, say, one second, the next would receive two seconds, the third would receive four seconds, the fourth eight seconds, and so on. On development, the density of each strip is measured, and over the whole period of normal exposure the density is found to increase by the same amount for each doubling of the exposure. If this amount is large the final density for maximum exposure will obviously be very great and we shall then get a vigorous contrast-giving negative. If the amount is small the densest part of the negative will not be of very great density, and the negative will accordingly be "soft."

SPEED

Owing to the speed of the 'plane over the ground a rapid exposure is necessary to procure an image devoid of any signs of movement. The fastest emulsion by the Hurter and Driffield criterion, however, is not necessarily the best and is not therefore selected, but one which will develop workable densities, as will be explained later, in the under-exposure region.

All films and plates used in this special branch of photography should be on the vigorous side, should possess fine grain and should be absolutely free from fog. It is often very misleading to state H. and D. numbers for plate speeds as they are arrived at in many different ways, although quoted by most manufacturers. Each individual determines in his own laboratory the plate or film speeds. On the H. and D. basis, however, the speed for aerial work in Great Britain should be at least 250, and preferably 400 or 500. The latter is essential for work during winter months and in dull weather at

PLATE No. 6.

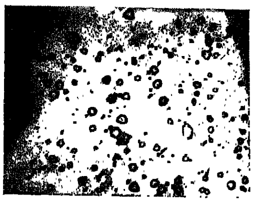
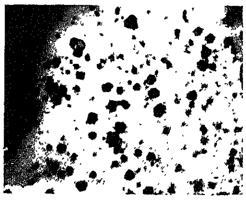


FIG. 15. GRAINS BEFORE DEVELOPMENT OF A PANCHROMATIC PLATE.



(*Imperial Dry Plate Co., Ltd.*)

FIG. 16. THE SAME GRAINS AFTER DEVELOPMENT, SHOWING PRACTICALLY NO ENLARGEMENT.

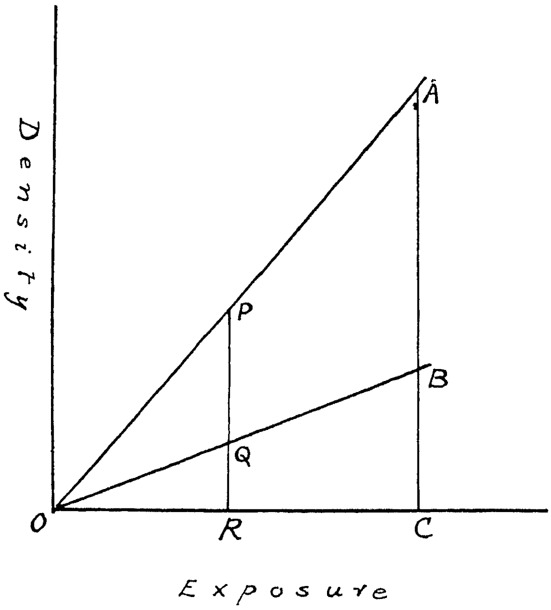


FIG. 17.

To face page 34.

other times. In the United States and other countries where the light is superior to our own it will be found sufficiently satisfactory to use plates and films of a speed of 150 to 200 H. & D. If sufficiently rapid, the lens can be stopped down to a smaller aperture; and a better definition, with slightly enhanced contrast, will be obtained. The degree of contrast can also be controlled to a great extent by the conditions of development.

COLOUR SENSITIVENESS

One of the most important features of the plate used for aerial work is the degree of colour sensitiveness. Three considerations rule this necessity. They are :—

(1) The terrain is covered with brightly coloured subjects.
(2) The atmosphere or haze between the camera and its objective.
(3) The scattered light, causing a superficial exposure of the plate.

To meet these problems partially we have the Iso or orthochromatic plate which is sensitive to green and yellow and must be used with a light yellow filter; it may be developed in red light.

But the only emulsion that is efficient all round is the panchromatic one, which meets all requirements and affords crisp contrast and excellent definition. The panchromatic emulsion is sensitive to all colours of the spectrum, i.e. to all visible colours, and in addition it possesses predominating sensitiveness to red, affording crisp contrast and excellent definition, thus making an ideal medium for aerial photography. Plates of this sensitiveness possess sensitometric values combining speed, contrast, latitude and considerable "shadow" detail giving powers when used with suitable filters (usually dark orange). Such plates, however, must be developed in complete darkness.

The *colour sensitizing* of plates dates back to 1873 when Vogel showed that by dyeing the sensitive silver salts in the film a pink colour with erythrosin, the green rays were absorbed and the silver bromide automatically became sensitive to green. It is not necessary for the dye used actually to make the silver salts themselves affected by

coloured rays, provided that the dye itself, or some compound formed by the interaction of the dye with a small fraction of the silver salts, absorbs them. There is an analogy to this in plant life, where the green chlorophyll plays the part of an optical sensitizer, enabling the plants to produce their food from the carbonic acid of the air and their own water by synthesis.

If we look at Fig. 18 we see the spectrum as photographed on an ordinary plate, and we see that it records the violet, blue and a portion of the green rays. In Fig. 19 we see the effect of colouring the sensitive emulsion with erythrosin—the green and greenish-yellow rays are now recorded in addition. Many years passed before any dye was discovered which rendered the plate *red*-sensitive, but to-day, by combining four sensitizers, we can make the plate sensitive to the entire visible spectrum, as shown in Fig. 20 where the whole range of colours is seen recorded with remarkable evenness.

Fig. 20, in fact, represents the type of plate so largely used in aerial photography. Combined with an orange filter, the absorption spectrum of which is seen in Fig. 20A, the operator can obtain a distinct photograph with good contrast under atmospheric conditions such that the eye can see very little.

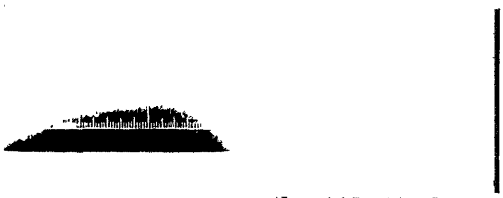
It is important to avoid the use of that type of light-filter which renders objects of all colours in correct shades of monochrome, *i.e.* in accordance with their visual luminosities. If this be done, a somewhat monotonous and "flat" result is liable to be obtained, because so many colours in a summer landscape are of very similar visual brightness and would be all rendered equally dark in the picture. A certain degree of falsity of colour rendering is necessary to give contrast and "point" to the pictures.

EXPOSURE

While exposure meters may be strongly recommended by some authorities, we have found that experience best enables an operator to estimate correctly what exposure should be made in given circumstances. In practice very little use is made of exposure meters. As we have already pointed out, the aerial negative that

PLATE No. 7.

SPECTRUM PHOTOGRAPHS.

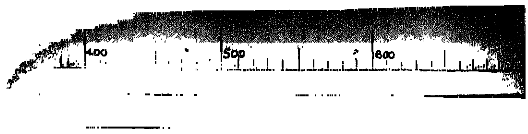


(*Imperial Dry Plate Co., Ltd.*)

FIG. 18. ORDINARY PLATE.

(*Imperial Dry Plate Co., Ltd.*)

FIG. 19. ORTHO-CHROMATIC OR GREEN SENSITIVE PLATE.



(*Imperial Dry Plate Co., Ltd.*)

| VIOLET | BLUE | GREEN | ORANGE | RED |

FIG. 20. IMPERIAL PANCHROMATIC PLATE, SHEWING COLOUR SENSITIVENESS TO THE COMPLETE RANGE OF VISIBLE COLOUR.

To face page 36.

PLATE No. 7A.

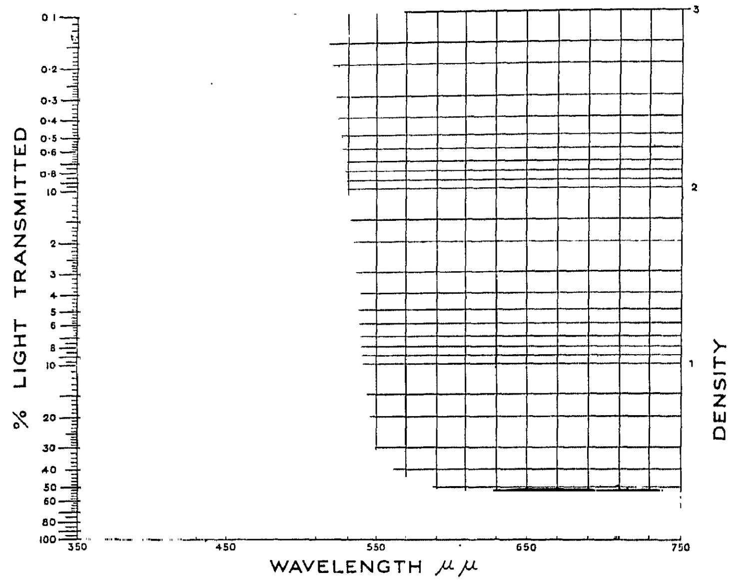


FIG. 20A. SPECTRO-PHOTO-METRIC CURVE OF ORANGE FILTER CUTTING OUT ALL ULTRA-VIOLET AND VIOLET RAYS, AND GREATLY DIMINISHING INTENSITY OF BLUE.

To face page 37.

shows slight under-exposure may often be preferable in that it provides a printing density sufficient to enable a maximum amount of contrast and detail to be recorded.

Exposures must be based on the following general conditions applying specially to aerial photography :

(*a*) The speed of the navigable platform (the aircraft) over the ground. Here it should be pointed out that the ground speed, as apart from the flying speed, is affected by the speed of the wind. The speed of the wind must be considered as a plus or a minus, according to whether the machine is flying with or against the wind, this plus or minus to be added to or subtracted from the flying speed of the machine.
(*b*) The vibration of the aircraft and its effect upon the camera.
(*c*) The type of plate or film being used, whether orthochromatic or panchromatic, and the speed of the emulsion.
(*d*) The type of lens being used, according to aperture, and its defining power.
(*e*) The type of filter and its density.
(*f*) The value of the light, which is controlled by the flying altitude, the nature of the ground below, and the time of day and year.
(*g*) The density of the atmosphere—or haze.

The main factor to be considered is the value of the photographic light compared with the visual light. An operator with an intimate knowledge of his camera and a certain amount of aerial experience should have no great difficulty in correctly estimating exposures, but it may be said without fear of contradiction that the longest exposure compatible with success is 1/50th of a second when a medium filter is used—and the fastest, on a suitable plate, 1/350th of a second. The variation for exposure which differs in various types of cameras is usually made by adjustments of the shutter according to the speed and variable slit. Also the lens is usually provided with an iris and when stopping down the exposure must necessarily be lengthened. As a practical example the following table will give some idea of exposures desirable in Great Britain, using a suitable panchromatic plate of say 300 H. & D. and lens F5·6 :—

March . .	1/150th to 1/200th
June . . .	1/200th to 1/350th
September . .	1/100th to 1/250th
December . .	1/50th to 1/100th

The following table of exposure factors (light values) reproduced by courtesy of the Imperial Dry Plate Co. Ltd., is worthy of careful study :—

TABLE OF LIGHT VALUES.

Greenwich Mean Time.

	12	a.m. p.m. 11 & 1	a.m. p.m. 10 & 2	a.m. p.m. 9 & 3	a.m. p.m. 8 & 4
June	1	1	1	$1\frac{1}{4}$	$1\frac{1}{2}$
May, July	1	1	1	$1\frac{1}{4}$	$1\frac{1}{2}$
April, August	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	2
March, September	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	3
February, October	2	$2\frac{1}{2}$	3	4	10
January, November	$3\frac{1}{2}$	4	5	12	—
December	4	5	6	16	—

	a.m. p.m. 7 & 5	a.m. p.m. 6 & 6	a.m. p.m. 5 & 7	a.m. p.m. 4 & 8
June	2	$2\frac{1}{2}$	5	12
May, July	$2\frac{1}{2}$	3	6	—
April, August	3	6	—	—
March, September	6	—	—	—
February, October	—	—	—	—
January, November	—	—	—	—
December	—	—	—	—

This table (for latitudes about 53°N) is suitable for exposures in the British Isles (except the Highlands of Scotland) Holland, Belgium, Denmark, N. Germany, Mid Russia and British Columbia.

In considering the light values to ascertain the exposure required, other governing conditions such as the general weather conditions, nature of ground, stop used on lens, and speed of plate or film, must be considered.

CHAPTER IV

NEGATIVE DEVELOPING

CONSIDERING the comparatively high cost of taking aerial photographs, no expense should be spared on small items such as the purchase of reliable chemicals, and the greatest care should be taken in the mixing of solutions and the development of plates and films. This chapter will refer throughout to Panchromatic material. The conditions of development should be such as to produce the highest possible speed together with a high degree of contrast, without producing grain or fog; for this reason branded developers of good density giving power and which do not unduly retard the speed of the plate by cutting out shadow detail, are employed. In other words, to produce the maximum detail in the shadows.

CONTRAST AND FINE GRAIN

It is better to use developers which will effectively show the maximum of under-exposed detail, with plenty of latitude for range of temperature.

The aim in an aerial photograph is to obtain maximum detail with maximum contrast. In ordinary photography these two features are not usually associated with each other, and different types of plates would be employed to obtain great contrast as against a "flatter" result, slow plates being used for the former and rapid plates for the latter.

The aerial photograph must give *contrast* combined with *fine grain,* although taken on a plate of high speed, and development therefore demands special consideration.

It has been shown that the resolving power of a plate depends largely upon the irradiation or internal spreading of the image, which is not directly proportional to the size of the silver bromide grain.

The diameter $\triangle$ of a tiny image has been shown to be related to the exposure by the formula :—

$$\triangle^{\frac{1}{2}} = a' \times b' \log 10\, E,$$

where E is the exposure and a′ and b′ are constants, while Goldberg showed the sharpness-factor S to be related to the development factor Y and the turbidity factor of the emulsion K as follows :

$$S = \frac{Y}{K}$$

This appears to hold good only when the development factor is about 1, *i.e.* the negative is of ordinary average contrast and density.

The finest grained images are undoubtedly obtained with a plate having a wide even range of gradation—a long " straight line portion " in the characteristic H. & D. curve—and the resolving power depends in addition, not only upon the wave-length of light used in exposure but also upon the character of the developer. Pyro and rodinal are better than edinol, for instance.

The grain of the image must not be confounded with the individual grains of the emulsion ; with some developers the latter grains agglomerate very extensively to form clumps, and it is these clumps which constitute the "grains" which are so objectionable in enlarging. If two parallel line images of equal width d are seen just separated in a negative, the resolving power R may be said to be given by the expression

$$R = \frac{1000}{2d},$$

or the number of lines distinctly seen per millimetre, d being measured in microns.

The production by suitable development, of fine-grained images depends on so many factors that it is difficult to lay down any rules. A vigorous developer is needed in order to obtain the type of negative usually required in aerial work, but vigorous developers are rather apt to give grain. Fortunately, the modern panchromatic

plate develops with great rapidity, and this assists in giving fineness of grain. With the metol-hydroquinone developer recommended, the Imperial Panchromatic plate takes only 90 seconds to give a bright, vigorous negative, the grain of which is sufficiently fine to admit of the biggest enlargement.

A good deal of work has been done with borax as an accelerator. A formula with borax for giving extremely fine grain is as follows :

Hot Water . .	40 ozs.	or	1000 c.c.	
Borax . . .	400 grains	,,	20	grammes
Metol . . .	40 ,,	,,	2	,,
Hydroquinone . .	100 ,,	,,	5	,,
Sodium Sulphite .	400 ,,	,,	20	,,

ELIMINATING THE EFFECT OF GRAIN

When, perhaps by accident, pronounced "grain" is found on negatives, there must be certain causes. As such accidents are disastrous, for enlargement purposes, we quote from *Photographie Moderne* :—

"The principal causes are (1) a chemical or a lantern-fog in the course of development ; (2) a too warm developer or one containing too much sulphite ; (3) a too warm or exhausted fixing-bath, or one without hardening material ; (4) too lengthy washing.

"For enlarging we recommend always interposing a ground-glass between the source of light and the condenser : the slight grain that may exist on the negative is then completely suppressed as are the inevitable small defects on the gelatine such as scratches, erosions, dust, etc. Another precaution is to clean the negatives lightly with turpentine before enlarging. In any case there is no question that an enlargement on glass or film is much better, softer and finer when a diffusing-screen (ground-glass) is interposed between the light and the negative."

DEVELOPMENT PROCESS

The actual development process is apt to be deceptive, especially to the operator who has hitherto been accustomed to only ordinary

photographic work. Supposing for instance an open dish be used; instead of the most prominent high lights appearing first, followed by the building up of the image tone by tone, an even veil will appear and very little detail will be visible. In aerial work development is continued until a faint outline of the most prominent object can be viewed through the back of the plate or film. From four to ten minutes, according to the strength and temperature of the developer, will elapse before the appearance of this outline. The usual temperature recommended by manufacturers is sixty-five degrees Fah., when under normal conditions three minutes to quarter of an hour is required.

Tank development is the method usually adopted and so long as the tanks are made of German silver there is very little chance of contamination from them.

In aerial work carbonate is used slightly more than in ordinary photographic practice in order to introduce a stain by which the printing density of the negative is increased. The necessity of increasing contrast, however, is becoming less and less, modern materials being greatly improved. It is now perhaps doubtful whether a stain is really necessary, but it may be left to the operator's discretion. Bearing in mind the other necessity of reducing grain as much as possible, the following formula for panchromatic material can be generally recommended, but plate or film manufacturers always supply their own formulæ which, of course, are usually carefully balanced.

PYRO-METOL DEVELOPER

No. 1.

Metol	45 grs.	5 gms.
Metabisulphite of Potass.	120 ,,	14 ,,
Pyrogallic Acid . .	55 ,,	6 ,,
Bromide of Potassium .	20 ,,	2 ,,
Water (boiled or distilled) to	20 ozs.	1000 c.c.

No. 2.

Soda Carbonate (Cryst.).	4 ozs.	200 gms.
Water (boiled or distilled) to	20 ,,	1000 c.c.

For use take equal quantities of No. 1 and 2.

In making up No. 1 dissolve the Metol in 12 ozs. of water, and the

Metabisulphite in 4 ozs.; when both are completely dissolved mix together, then add the Pyro and then the Bromide, and make up to 20 ozs.

"M.Q." DEVELOPER.

Metol	50 grs.	5·5 gms.
Sodium Sulphite	500 ,,	57 ,,
Sodium Carbonate	500 ,,	57 ,,
Hydroquinone	40 ,,	4·5 ,,
Potassium Bromide	25 ,,	3 ,,
Distilled Water to make	20 ozs.	1000 c.c.

The chemicals should be dissolved in the order given.

The English and French measurements are not to be considered as equivalents but their proportions are the same.

TANK DEVELOPMENT FOR FILMS

The following formula is used mainly for air survey films and tank development. This formula is sufficient for one hundred exposures.

PYRO-METOL (Aerial) DEVELOPER (Stain).

No. 1.

Metol	6 ozs.
Potassium Metabisulphite	$7\frac{1}{2}$,,
Pyrogallic Acid	$7\frac{1}{2}$,,
Potassium Bromide	3 ,,
Water up to	160 ,,

No. 2.

Sodium Carbonate	9 lbs. (if anhydrous, $4\frac{1}{2}$ lbs.)
,, Sulphite (Cryst.)	$1\frac{1}{2}$,,
Water	22 gallons.

The above formula may be used for tanks holding twenty-two gallons. We should advise that the chemicals should be made up as shown in two "Winchester" quart bottles (160 ozs.) This is in place of dissolving the chemicals in No. 1 solution in eleven gallons of water. The sodium carbonate and sodium sulphite may be dissolved in the development tank itself. When the film is ready, both bottles of

No. 1 solution should be added and stirred well. With a temperature of sixty degrees Fah. development will occupy from three and a half to five minutes.

Panchromatic plates or films must in the ordinary way be unloaded in complete darkness and must not be exposed to any light until development has been completed and the operation of fixing has begun. Later we show how this may be avoided.

When tanks are used, the plates or films should, after coming out of the developer, be thoroughly rinsed in water before they are put into the fixing bath, otherwise Diechroic fog will occur if the caustic alkali is carried into the fixing bath.

FIXING BATH.

Hyposulphite of Soda .	1 lb.	300 grms.
Potass. Metabisulphite .	2 ozs.	40 ,,
Water	50 ,,	1000 c.c.

As usual, the Potass. Metabisulphite is introduced to stop further developing action and insures clear and bright negatives.

If the bath is fresh, fixing will be completed as soon as the negative has cleared, but it may, in some circumstances, be advisable to prolong the process to ten minutes or quarter of an hour. A used-up bath should not be used, otherwise uneven staining will result. The plates or films should be left in the fixing bath for a few minutes before the light is turned on.

NEGATIVE WASHING AND DRYING

Plates should be placed in siphon tanks and should be fed continuously with water. Films should be wound on to a rota, drum or frame, and fed in the same way. When the operator is sure that sufficient washing has been effected to the emulsion side of the plate, it should be wiped with cotton wool before being placed out to dry. For a continuous strip of film we recommend the use of a soft wash-leather which should be rubbed over the surface before the film is wound on to the drying drum.

For drying, plates should be placed on their edges in wooden racks in a flow of dust-free air. The space between the plates should be

sufficient to allow of even drying. Quicker drying is obtained by putting the plates in a bath of methylated spirits for a few minutes. This will displace all the water, and after the emulsion has been removed, drying will follow quickly on the evaporation of the spirit. Films on a drying drum can be revolved by a small motor in order to speed up the drying process.

DEVELOPING IN THE TROPICS

As a great deal of aerial photography is carried on in tropical countries, it may be as well to say a word or two about development under excessive heat. Plates or films should be developed in the early morning where the normal temperature during the day is anywhere near 92° Fah.

The temperature of the chemicals should be kept down as much as possible by keeping the water for the solutions through the night in porous earthenware pots. When temperature is about 85°, the following is a useful developer:

Amidol	75 grs.
Soda Sulphite, anhydrous . . .	1 oz.
Potass. Metabisulphite	100 grs.
Water	20 ozs.

The development will be rapid (about 1½ mins.) and there should be no signs of softening of the gelatine. The plates require a quick rinse and should be immediately placed in a suitable *hardening fixing bath.*

A.		B.	
Potass. Metabisulphite	2 ozs.	Chrome Alum . . .	½ oz.
Sodium Hyposulphite	1 lb.	Water . . .	20 ozs.
Water . . .	20 ozs.		

Make up A and B separately, as they will keep for some time, and mix in equal quantities.

Full hardening and fixation is necessary, after which a careful washing by a number of changes and swabbing over the emulsion is

necessary. It may be essential to place the negatives in a fine gauze receptacle to combat the dust usually found in such atmospheres.

EFFECT OF TIME AND TEMPERATURE ON Y

In order to understand the behaviour of a photographic plate or film on development, it is necessary to get a clear idea of the way in which a dry plate functions on exposure and development and of the ways of measuring and classifying this behaviour.

1. What the film of a photographic plate consists of :—

The emulsion with which a plate is coated consists of a large number of small grains of crystals of silver bromide embedded in a layer of gelatine. (Fig. 21.)

2. How these grains behave on exposure and development :—

On exposure to light the grains are apparently unaltered, but on treatment with a developer it is found that certain grains have been so altered that they become blackened or reduced to metallic silver. The time taken for a grain to become completely reduced once the process has started is an extremely brief one. The amount of light necessary to produce this effect is also a perfectly definite quantity; any light below a certain intensity in a given time will be without action on the grains. A measure of this light is known as the "sensitivity" of the grains.

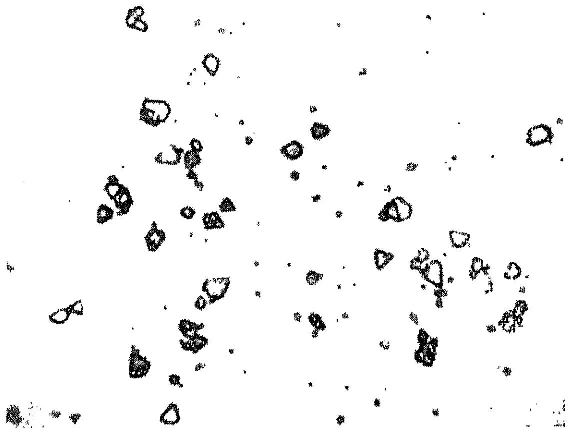
Bearing these facts in mind, we can visualise the mechanism of exposure in a plate by the following :—

The sensitive emulsion contains a large number of grains which may be grouped into a number of groups according to their sensitivity.

Thus we can conceive the emulsion to be made up of several classes of grains, each of a different degree of sensitivity.

The basis of the Hunter and Driffield system for measuring the characteristic curves of plates, is to expose to a light of fixed intensity consecutive strips for geometrically increasing times—1–2–4–8–16 seconds. It is developed, fixed and washed; and the amount of silver per unit area is measured by the light-stopping power of the film or opacity, which has a simple relationship to the amount of silver per unit area, known as *Density*.

PLATE No. 8.



(*Imperial Dry Plate Co., Ltd.*)

FIG. 21. GRAINS OF CRYSTALS OF SILVER BROMIDE IN EMULSION OF PLATE.

To face page 46.

PLATE No. 9.

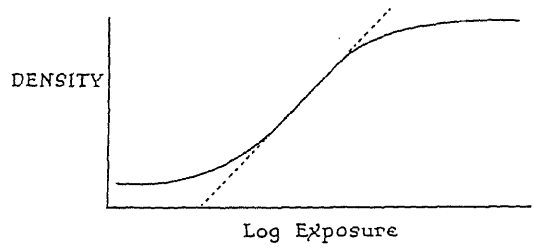


FIG. 22.

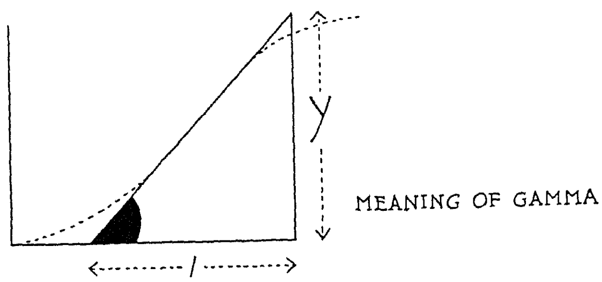


FIG. 23.

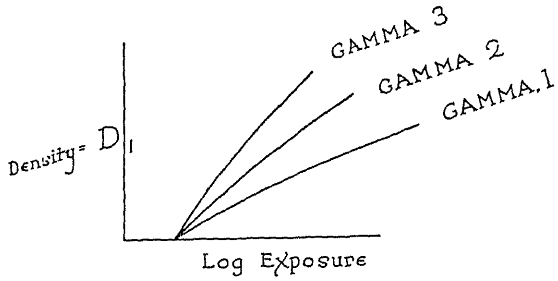


FIG. 24.

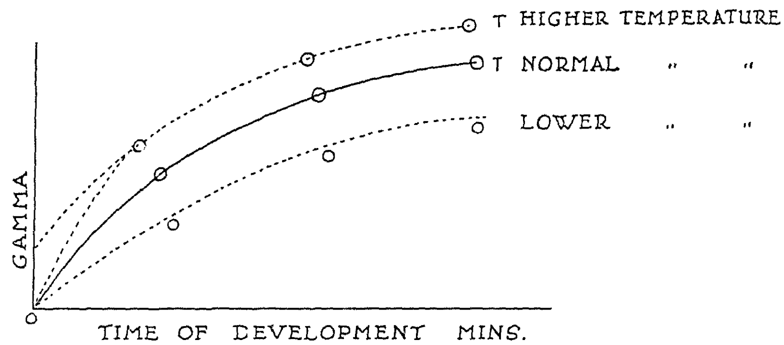


FIG. 25.

To face page 47.

On plotting the values obtained for densities against the geometrical exposures, we get a smooth curve which is the characteristic of the emulsion under test. In practice each end of the curve is not a straight line, the whole curve being S shaped. (Fig. 22.)

EFFECT OF ALTERING THE TIME OF DEVELOPMENT

The effect of prolonging the development time is to reduce a greater number of grains and thus to increase contrast. The curves are thus made steeper. Hunter and Driffield introduced a method of measuring this contrast value by taking the tangent of the angle which the straight line portion of the curve makes with the exposure axis. The result is called the development factor or Y (gamma) value of the plate. (Fig. 23.)

It will be seen that when a plate is developed to any definite Y it is possible to determine the shape of the straight line portion of the curve.

If a plate is taken, exposed in steps, then cut into three or more strips—each strip being developed for a different time—we get three curves of different Y. (Fig. 24.)

These, if plotted against time of development, give a curve from which we can determine the time of development necessary to produce any required Y. (Fig. 25.)

EFFECT OF TEMPERATURE ON DEVELOPMENT

The effect of increasing the temperature of development is the same as increasing the time of development, thus the higher and lower the temperature within limits, the higher or lower the gamma produced for the same time of development.

The lower limits of temperature are governed by the effective temperatures at which some developers will work. For example, Hydroquinone will not develop satisfactorily below 60° F. The upper limits are governed by the excessive fog-producing qualities in some developers, although in most cases this is higher than the melting point of the film.

IMPERIAL PANCHROMATIC "B" PLATES

As these plates are sensitive to all colours it is essential that they be developed in absolute darkness, or with a Panchromatic Safelight. Feeble white, or bright green, illumination can be used after the first 1½ minutes if D.S. (desensitized) backed plates are employed.

The times of development are as follows :—

Character of Negative.	Development Factor (gamma)	"M.Q." Developer			Pyro-Metol Developer		
		at 60°F.	at 65° F.	at 70° F.	at 60° F.	at 65° F.	at 70° F.
		m. s.	m s.	m. s.	m. s.	m. s.	m. s.
Soft . .	0·8	1 30	1 20	1 15	1 45	1 30	1 10
Medium .	1·0	2 15	1 50	1 30	2 30	2 0	1 36
Vigorous .	1·3	3 30	2 45	2 30	4 0	3 30	3 0

The multiplying factors when using Imperial, Ilford or Wratten filters are as follows, assuming that the exposure to daylight is represented by the figure *one* :—

	Daylight.
"Impan" (full colour correction in monochrome) .	2½
Ilford Gamma	6
Wratten K3	3½
Tricolour Blue	3
Tricolour Green	10
Tricolour Red	7

FIG. 26.

A similar Chart to Fig. 26 is enclosed with some makes of plates and films giving time and temperature tables for one or two developers. These values are checked in the laboratory for each batch, but will not be found to vary greatly the standard shown.

The question as to what Y to develop to, is one which the character of the aerial subject must control. The *theoretically* perfect negative is one developed to a Y of 1, since then the amount of light stopped is directly proportional to the amount of light reflected from the

original. This is, of course, assuming that a transparency is being made on the same class of sensitive material as is used for the negative.

The usual printing medium, however, is a bromide or gaslight paper, which can be obtained in varying degrees of contrast. The usual method is to develop to such a gamma as will suit the range of intensities reflected from the subject. For example, three subjects present themselves:

A. Flat landscape range of Intensities. 1–5.

B. Open. Landscape Intensities. 1–15.

C. Extreme cases, up to 1–60.

DESENSITIZING

In the opinion of many workers, one of the greatest objections to panchromatic plates in ordinary ground photography has been the belief that development had, of necessity, to be carried out in complete darkness. This is true to some extent, as we have said, but the discovery of practicable desensitizers has removed the drawback, and development of panchromatic plates may be now carried out in yellow light. This applies equally to aerial plates. It is wise to examine more closely—after say one minute's development—the progress of the work, and finally to examine the negative to make certain that sufficient development has taken place. This is particularly desirable when the subject and atmospheric conditions have varied considerably. There is no reason why a desensitizer should not be used in the developing tanks for roll films for survey work, for this enables a more careful examination to be made in a yellow light during the development. Desensitizing can be divided into two groups:

A. Safranines and their Congeners.

B. Coccin, Pinacryptol green, and the like.

The Safranines and their allies are quite reliable desensitizers when used as shown in the formula following. They have, however, this disadvantage—they impart a stain to the gelatine film, the elimination of which means a good deal of washing, but apart from this they are cheap and more or less effective.

Pinacryptol is the most efficient desensitizer now made. It is safe, even at a dilution of one in a thousand. There is no risk of stain and the plates need only a brief rinse before they are placed in the developer.

Coccin is now used hardly at all. While some operators place desensitizers in the developer it is our opinion that desensitization should be an entirely separate operation.

FORMULÆ FOR DESENSITIZERS.

Pinacryptol Green.

(Sold in 1-gramme tubes).

Dissolve 1 gramme in 500 c.c. (20 ozs) Water for Stock solution.
For use, 1 part of Stock to 19 parts Water.
The solution keeps well and may be used over and over again.

Safranine.

Use in part in 2000 Water or according to maker's instructions. After development and fixing, the stain may be removed to a large extent by the use of the following bath:

Conc. Hydrochloric Acid . .	1 oz.	20 c.c.
Potash Alum	½ oz.	10 grammes.
Water	19 ozs.	400 c.c.

Followed by a thorough washing.

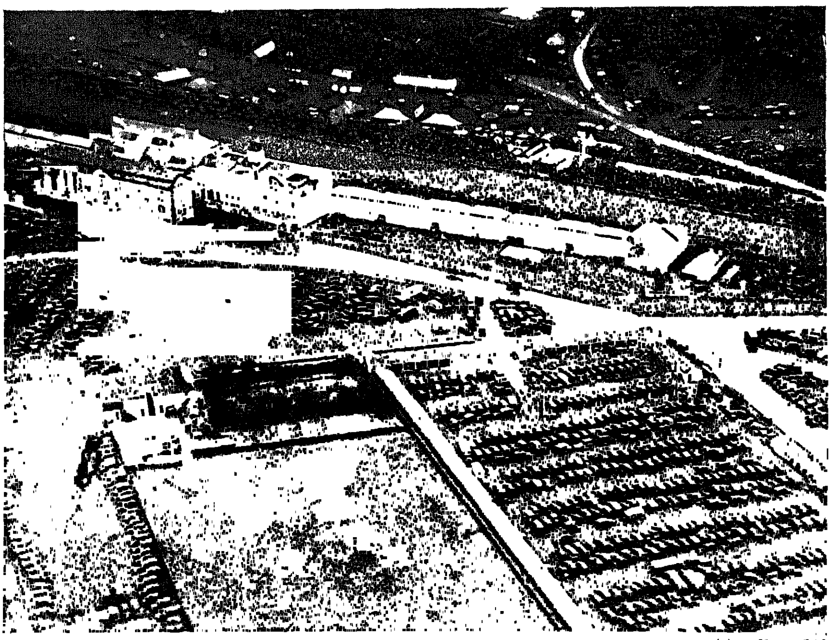
Desensitization.

The plates are unloaded in complete darkness and placed in a dish or tank containing the desensitizer, either Pinacryptol Green or Safranines, for one minute. They are then rinsed and placed in the developer. A good yellow safelight or a candle may be used as a source of light during development.

DESENSITIZED BACKING TO PLATES

Some manufacturers introduce a desensitizing solution into the backing of the plate so that it acts directly the plate is received by the developer. Various users have complained of a slight fogging, and it is therefore almost imperative to make a thorough test with the plate or section of the film in order to see that it acts correctly in varying strengths and lighting. It may be interesting to note the experience of others in the use of desensitized backing. *The Amateur Photographer* says:

PLATE No. 10.



(*Aerofilms, Ltd.*)

FIG. 27. THE DERBY. (THE HORSES CAN BE SEEN APPROACHING THE WINNING POST). TAKEN WITH A HYPERSENSITIZED PLATE ON A WET DAY.

To face page 51.

"We have recently had an opportunity of using 'Imperial Panchromatic' plates with the new 'D.S.' backing, and found that it worked perfectly. The plates bore a comparatively thick layer of backing material, and were placed in the developer in the dark, or, if preferred, in the usual non-actinic light. We used the ordinary pyro-soda formula, the backing giving this in a very short time a dark purple colour. The photographer is advised to lift the plate off the bottom of the dish once or twice, rocking in the meanwhile, so as to make quite sure that the liquid has free access to the backing, which very soon dissolves. After the lapse of a minute, the operation can be completed by white light, such as a candle, without any risk of fog. We got perfectly clean negatives on both kinds of plates named when working in this way. An acid hypo bath, such as is used for bromide or gaslight paper, is recommended to remove any stain which may be caused by the desensitizer.

"It will be seen that the dark room, as that term is usually understood by photographers, is thus rendered unnecessary. There is no difficulty at all about putting the plates into the developer in perfect darkness, if a sufficient quantity of solution is used to make quite sure that they are covered; and the red light is, therefore, not required. There is, of course, the added advantage of freedom from halation conferred by the backing. Such a change as this opens up a wide vista of possibilities in the future; as it has always been recognized that there is no greater deterrent from photography than the supposed necessity for some form of non-actinic light. This has been done away with in the case of roll film by the introduction of developing tanks, and the new backing seems to be a big stride in the same direction in the case of plates."

HYPERSENSITIZING

This is the means of increasing the speed of the emulsion and in certain circumstances is a very useful process. When the light is poor during operations, or when the normal speed of emulsion of films is rather on the slow side, it is possible to get well-exposed results by hypersensitized plates or films. By hypersensitizing, the operator who was taking photographs of the Derby at Epsom when the sky was completely obscured by cloud, and rain was falling heavily, achieved results equal to those obtained on a brilliant day. (Fig. 27.)

The manufacturer will tell us that the effect of hypersensitizing will not last long as it very soon goes back to its normal speed. In America, where the material is kept on ice, the commercial aerial companies find from experience that films so treated retain their extra speed for several months.

FORMULA FOR EXTRA SENSITIZING PANCHROMATIC PLATES.

Industrial spirit (this must contain no dye, and must not show any milkiness with water)	75 c.cs.
Water	25 c.cs.
Ammonia S.G. ·920	2 c.cs.

Bathe the plates and films in complete darkness in this solution for three minutes at 65°, and at once dry in a current of dry dust-free air, which should be about 80° Fah.; the increase of speed obtained is about 100%.

Another method is to wash the plates or films for one or two hours in running water and re-dry. This gives an increase of speed of 20 to 30% to green and red, but plates as treated should be used quickly, say within twenty-four hours, as they do not keep well.

NEGATIVE INTENSIFICATION AND REDUCTION

The aerial negative, as a rule, will be on the under-exposed or thin side, and it is quite rarely that a very hard negative is secured except at much over-exposure, so that the question of reduction is hardly involved. Where it is impossible to secure a "contrasty" result, even by using the hardest of printing paper, intensifying is sometimes adopted. Its disadvantage is that it gives rise to far too much "grain" effect to the negative. The usual chromium, uranium or mercury intensifiers may be safely used if the negative has been thoroughly washed and is free from hypo. The uranium intensifier is best for under-exposed thin negatives, that is, negatives which have not attained good density, even after long development. If, however, negatives are clear and bright, although under-developed, the chromium or mercury and ferrous oxalate intensifier is suitable and can be applied more than once if necessary.

REGISTRATION AND RECORDING

To retain a proper record of oblique and vertical photographs taken, each exposure made must be given a serial number, which should be marked on the emulsion side of the negative in the rebate

by pen and indian ink. A register bearing the numerically arranged figures will supply the necessary data, such as location of the subject, the date the photograph was taken and the time of day, with any other necessary information. In the modern types of film cameras, the serial number of each exposure is automatically recorded.

The Oblique.

In the case of oblique pictorial views, where large quantities are taken of varying subjects, apart from the usual register arranged in numerical order, a very careful cross reference system is necessary. Subjects should be classified under different headings and two registers at least are required. One for location, each view being recorded under its district or town alphabetically, stating the name of the town or place, with all negative reference numbers, alongside of which will be placed the respective descriptions of the negative, *i.e.* The High Street and Parish Church looking E. The second book is a classification register of subjects, alphabetically arranged so that all Cathedrals, Rivers, Racecourses, Geographical features, etc., are brought together under these headings, again stating the location and negative number. When a company has a large demand for their views from the Press and other sources, this latter reference is indispensable. This system can also be very satisfactorily carried out by the card index method.

Commercial aerial photographic companies, who are also engaged in photographing properties of industrial concerns for advertising purposes, keep a separate record, alphabetically arranged under the client's name. The negative numbers and any other useful details are again stated.

In addition to the above, it is perhaps advisable to retain a photographic record of each negative in album or card index form.

The Vertical.

In aerial surveying, each negative is recorded in registers or on card indices stating serial number, location, map reference, date, time of day, height taken, focal length of lens, type of camera used, etc., and a cross register under districts and/or map references. Once

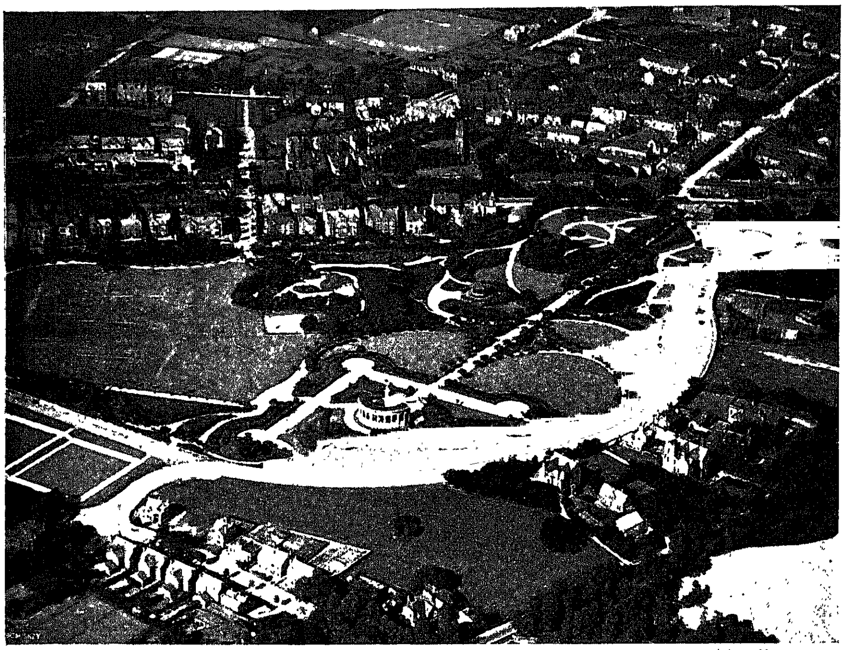
a scale rectifying data has been determined, all this information should be recorded and registered.

In some instances it is useful to record on the existing map covering the area surveyed, the negative numbers, placing them in centre of the area covered by each vertical photograph respectively. This is known as the key plan.

Too much importance cannot be placed on the necessity of keeping very thorough and careful records.

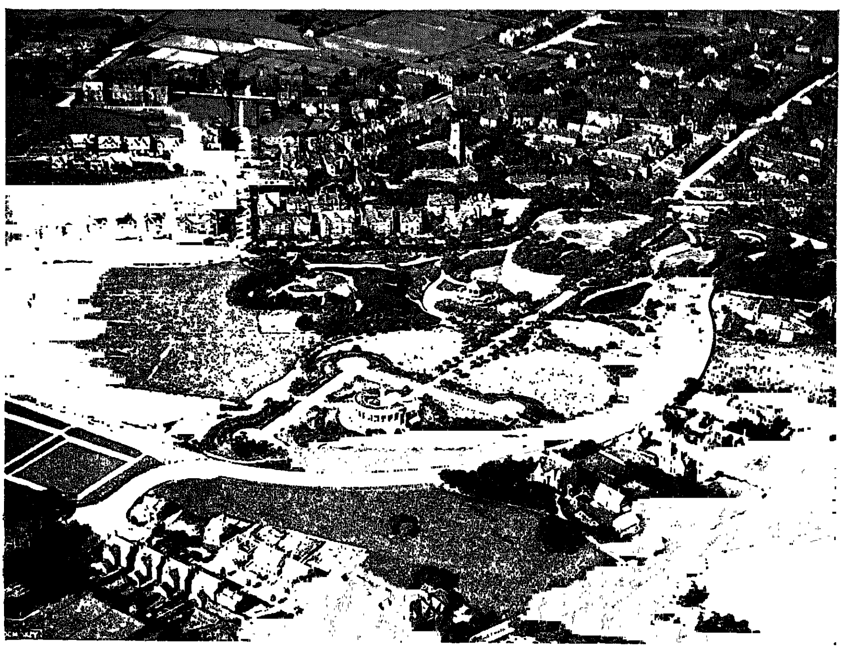
After this, the plate or cut film should be cleaned and stored in transparent paper bags. The boxes containing these bags should be suitably marked and indexed. Roll films are a great convenience, as little storage room is necessary for them. By special printing machines copies are made direct from the rolls, without the necessity of cutting or separating each exposure. They are stored in boxes and kept in the usual fire-resisting safes.

PLATE No. 11.



(*Aerofilms, Ltd.*)

FIG. 28. GREENHEAD PARK, HUDDERSFIELD. THE ORIGINAL PRINT WAS MADE ON A "SOFT" GRADE OF BROMIDE PAPER.



(*Aerofilms, Ltd.*)

FIG. 29. PREPARED FROM THE SAME NEGATIVE, BUT WITH A "CONTRASTY" GRADE OF PAPER. THE GENERAL EFFECT IS MORE CRISP AND BRILLIANT.

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CHAPTER V

PRINTING PAPERS

The most suitable papers for aerial photography are those given to high contrast. " Bromide " paper is mainly used, but " gas light " has its advantages for thin negatives. The surface of the paper or emulsion is generally glossy when the work is undertaken for commercial purposes. There are so many good papers on the market that it is not easy to make distinctions. Illingworth's " Press " or Wellington Ward's " Enammo," which are prepared in different grades to enable any type of negative to be matched, are very reliable. The glossy and semi-matt surfaces give the best results. (Figs. 28 and 29.)

It is customary to give a short exposure and long development, as the papers mentioned increase their contrast with continued development. We have already shown that the majority of aerial negatives are enlarged through a projection camera, which helps to improve the rendering of high lights as well as the dark shadows, and enables a certain amount of shading to be effected.

THE EMULSION

The sensitometry of papers is very similar to that of plates, only with this difference; the reflecting powers of the one take the place of the transparency of the other. If bromide paper is used it must be handled and developed very carefully under a safe light—usually ruby, orange or yellow—as its coating is a bromide of silver emulsion highly sensitive to light. The emulsion should afford good latitude and considerable gradation, and should also yield strong and pure blacks, clean high lights and a full range of half tones. For pictorial work of an oblique nature, prints are sepia-toned by the usual methods, that is to say, by sulphide or hypo alum. The paper must be chosen

with discretion, and should match the negative so that a considerable range of tones from clear white to black, is given.

The following amidol formula can be recommended for good tones and clean working:

AMIDOL DEVELOPER.

Sulphite of Soda (Crystals)	1¼ ozs.	60 grms.
Potassium Bromide .	10 grs.	1 grm.
Water . . .	20 ozs.	1000 c.c.
Amidol . . .	50 grs.	5 grms.

The amidol should be added when the rest of the solution has dissolved.

Some photographers prefer "M.Q." Developer, but with this the blacks are not so pure and the prints do not give such excellent tones.

METOL HYDROQUINONE DEVELOPER.

Metol	7 grs.	·7 grammes.
Hydroquinone . . .	30 ,,	3 ,,
Sulphite of Soda (Crystals) .	220 ,,	22 ,,
Carbonate of Soda ,, .	400 ,,	40 ,,
Bromide of Potassium .	10 ,,	1 gramme.
Water	20 ozs.	1000 c.c.

Dissolve in the above order. This developer keeps indefinitely in a well-corked bottle.

FIXING

After development prints should be passed through cold water before being placed in the following fixing bath, where they should remain at least fifteen minutes.

ACID FIXING BATH.

Hypo	2 ozs.	100 grammes.
Water	20 ,,	1000 c.c.
Meta-bisulphite of Potassium	½ oz.	20 grammes.

PRINT WASHING

After fixation the prints should be well washed in running water. There are very many types of washers, but the cascade or rotary types are more popular than any others. Water running continuously is essential, and on no account should prints be allowed to lie against each other, otherwise the hypo will not be properly removed.

The length of the washing operations depends a great deal upon the apparatus used, requiring anything from 15 minutes to one hour.

HARDENING

When required the following hardening baths may be used:

ALUM.		FORMALIN.	
Alum . . .	2 ozs.	Formalin (or 40 per cent. (solution Formaldehyde)	1 oz.
Water . . .	20 ozs.	Water . . .	20 ozs.

PRINT DRYING

Prints with a matt surface are usually put through a drying machine heated by gas and rotated by an electric motor. When rotated on a drum they are easily dried and no creases follow the operation. If a glaze is required and a glossy paper is used, prints should be placed on to plate glass whose surface has been treated with a preparation of oxgall or some similar glazing solution procurable on the market. Ferrotype plates are also used for giving a glazed effect and this system is chiefly adopted for press work. There are, of course, other ways of print drying, but the above have served us best in our own experience. For speed the same process of using methylated spirit as for plates is used except that the spirit is evaporated off after coming out of the bath.

EXPANSION AND CONTRACTION

The expansion and contraction of enlargements and prints depends entirely on the paper manufacturer. The ordinary type of print

paper expands considerably and, owing to the nature of the manufacture, more in one direction than the other. When wet it stretches, but during the drying process it goes through a certain amount of contraction although it never returns to its original size. The expansion will vary according to temperature, the texture of the raw material and to the conditions of washing and drying. In pictorial work little importance is attached to this problem, but for aerial survey it proves a distinct and sometimes troublesome disadvantage. In constructing a mosaic map, the expansion and contraction, not varying proportionately according to length and breadth of the paper, seriously interferes with true scaling. Precautions are taken according to the degree of accuracy required; precautions, that is, in the handling and mounting, but we fear that as long as paper is used as the base of reproduction, this defect will not be overcome. These slight inaccuracies, however, are averaged out over the whole map and do not therefore cause any serious discrepancies. When it is necessary to draw maps to scale from photographs with the greatest accuracy, it is advisable to use glass or celluloid on which the sensitized emulsion is coated. The image is projected and printed on the glass, and this, being transparent and illuminated from behind, it is possible for the draughtsman to trace the outline.

PART III

APPARATUS

CHAPTER VI

LENSES

THE general principles of optics as applied to lenses used in photography from the air do not in any way differ from the principles generally applied to lenses for terrestrial photography.

We will briefly explain what takes place when an object is projected on to a focussing screen by a lens. Light rays travel in straight lines, (at least, we may presume them to be straight for our purposes, in spite of Einstein's theory of curved rays), such rays being scattered from the surfaces of things we see about us. Some of these rays reach our eyes so that we see for example a distant steeple. Rays, on entering the eye, are bent in such a way that an image is formed on the surface of the retina. Up to this point the camera and the eye are identical in their performance.

Theoretically, lenses are only able to form a critically sharp image of objects in one particular plane. Points outside this plane are reproduced upon the photographic plate as small discs of light. Provided the diameters of these discs do not exceed a certain size the image is considered to be sharp. From this it will be seen that in practice photographic lenses have a depth of focus. Although this depth of focus is of great importance in terrestrial photography it is of little account in aerial photography. This enables lenses of large aperture and long focal length to be used in the air without re-focussing. The usual aperture ratio for aerial lenses is f4·5 to f8, the latter for long focus lenses (up to 60″) of the tele-photo type.

It it well known that with the highest class of anastigmat, which is usually designed to cover a comparatively large plate, the definition between the centre and margin is slightly impaired owing to the great covering power necessary for general purposes. In aerial photography it is considered that better definition over the whole of the plate is more advantageous than a wide angle. This demand for critical

definition has forced manufacturers to calculate and design special types of lenses which are more suited for aerial photography.

To construct a lens of small aperture giving good definition over a narrow-angle field is comparatively easy because the problems which have to be satisfactorily solved are mainly those of chromatic and spherical aberrations but directly the aperture of the lens and angle of the field increase, the difficulties become disproportionately great because questions of astigmatism, coma, flatness of field and distortion are introduced. Designers aim to balance the residual errors in order to secure as perfect an image as possible. Distortion known as "barrel" and "pin-cushion" would be a serious fault in a lens used for aerial work; thus, similar precautions have to be taken in the design as are adopted in lenses which are used for copying maps and, by careful design, this error can be corrected to such an extent as to be immeasurable on the plate. (Figs. 30, 31 and 32.)

Although manufacturers test all lenses before they are put on the market, it is none the less advisable to subject the lenses to further tests from time to time owing to the varying conditions under which they are used. The method adopted is to photograph a specially designed chart which will detect any fault in covering power, flatness of field or want of quality of illumination over the plate.

The essentials of an ideal aerial lens may be summed up as follows:

Type: Anastigmat, large aperture and fixed focus.

Definition: Critical defining power by use of the finest optical glass and perfectly spherical surfaces throughout the lens system.

Distortion: Freedom from distortion obtained by scientific balancing of the elements.

Illumination: Even exposure over the whole plate obtained by making the thickness of the lens as small as possible compared with its length.

FOCAL LENGTH

Aerial lenses are of the fixed focus type, as during flight the distance of the earth's surface can be considered to be at infinity. Once the

PLATE No. 12.

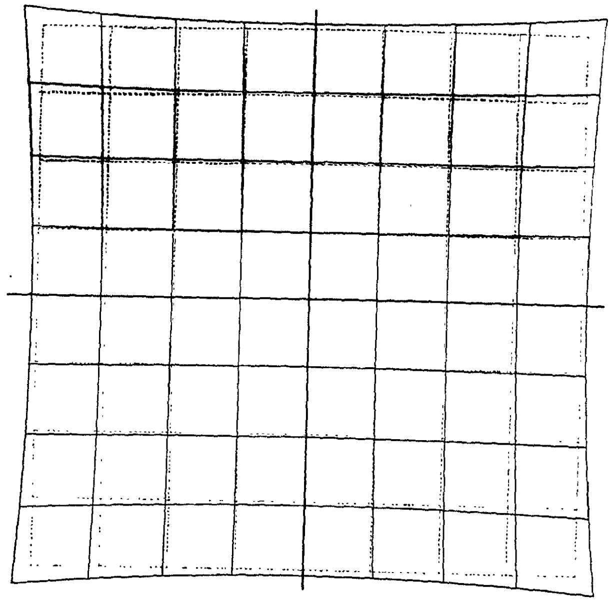


FIG. 30. EXAGGERATED "PIN-CUSHION" DISTORTION.

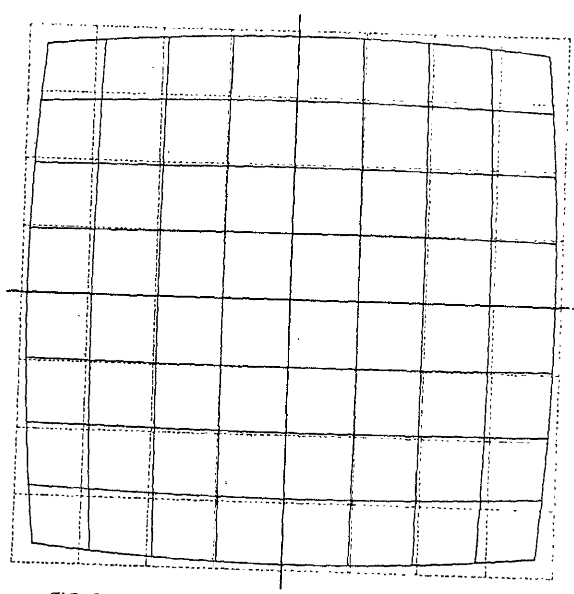


FIG. 31. EXAGGERATED "BARREL" DISTORTION.

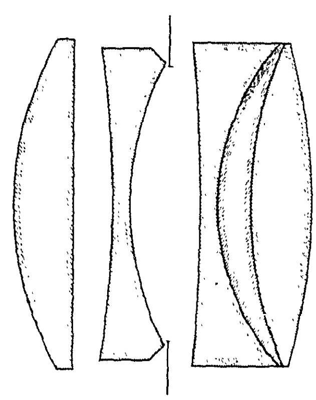
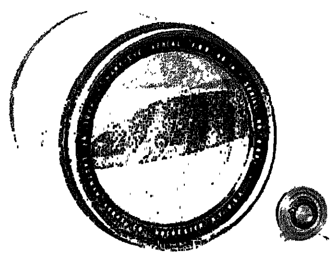


FIG. 32. ARRANGEMENT OF ELEMENTS. ROSS AIRO XPRES LENS, F4.5.

To face page 62.



(*Hamilton Maxwell.*)

FIG. 33. AN EASTMAN KODAK 48-IN. LENS, COMPARED WITH ONE OF THEIR AMATEUR CAMERA LENSES.

To face page 63.

lens is fixed at its proper focus all objects will be sharply defined regardless of the altitude at which the exposure is made. Focal length is measured from the image or face of the plate to some point in the lens known to the opticians as the nodal point. In the normal type of lens this nodal point is situated somewhere about the centre of the system or near the diaphragm, but in the telephoto lens the nodal point is well in front of the lens so that the focal length is considerably longer than the back focus. (By back focus is meant the distance of the last lens surface of the objective from the plate). A two-power telephoto lens of 40″ focus can therefore be fitted to a camera that would normally take a 20″ lens. The foci of aerial lenses vary from 8″ to 60″ covering plates from 5″ × 4″ up to 18 cms. × 24 cms. Short focus lenses of about 6″ focus are sometimes employed for vertical work in order to cover a large angular field and also for reconnaissance mapping to enable a large territory to be covered from great heights. These wide angle lenses can only be used when slight distortions are of no moment and great accuracy is not essential to the work in hand. The use of long focus lenses of 20″ and more with a relatively small plate restricts the field, but is particularly suitable when large scale photographs are required for greater accuracy. The lens of intermediate focus such as the 8″ and 10″ is chiefly used for oblique aerial photography. (Fig. 33.)

ILLUMINATION

The earlier lenses for air photography were supplied with fixed diaphragms as it was thought the maximum light intensity given by the full aperture of the lens was only just sufficient for the purpose of taking photographs from the air. Later practice has shown that an iris diaphragm, consisting of a series of thin metal leaves which open and close, is a useful adjunct to the lens.

LENS MOUNTS

Photographic lenses consist of one or more elements mounted in cells which are in turn screwed into position in the lens mount. The whole is held by a thread suitable for screwing to the body or cone of

the camera. The lens can be turned in the flange for initial focussing and when in the proper position it is clamped by a set screw or some similar device. The cone or body to which the lens mount is fixed is generally made of metal to withstand wind pressure and rough usage. For mapping work it is advisable to have a number of adaptable barrels, suitable for the different sizes of lenses used, arranged according to focal length to facilitate quick changing and to avoid the necessity of refocussing. Manufacturers of modern cameras include a range of lenses complete with cones or barrels as part of the ordinary equipment supplied.

In the next chapter we show that the best type of filter is one with glass mounted in a metal holder, clamped by a counter cell and then locked in front of the lens mount by some bayonet catch device. Most manufacturers supply interchangeable filters for their lenses.

Focussing can be done by means of the parallax method. A plain glass screen marked with horizontal and vertical lines is placed at the back of the camera. Taking some point over 400 yards distant the lens is moved within its thread until a position is found in which the image and the cross-lines do not move relative to one another when the head is moved from side to side. At this point the lens is locked.

It is not always easy to carry out the test on a distant point and by use of the collimator an artificial infinity can be substituted. The collimator consists of a well corrected telescope objective with a graticule or cross-wires at its focus. All rays emanating from a point on the graticule leave the collimator lens parallel to one another, so that in effect this point can be considered to be at infinity. The camera, with lens to be adjusted, is placed in front of the collimator and the correct focussing done by the parallax method described above.

EFFECT OF TEMPERATURE

Monsieur L. P. Clerc stated in a paper given to the Royal Photographic Society of Gt. Britain as follows: "While the British and American Opticians have succeeded in producing special lenses of fine quality with a larger relative aperture than the French, who were insufficiently supplied with optical glass of the requisite qualifications, it seems that insufficient attention has been paid to the variation of

the focal length and of the location of nodal points when the temperature is lowered, as it is at a height of 15,000 to 20,000 feet, frequently attained in wartime, and a very convenient one for precise topographic work. A Berthiot's Olor lens of 21″ focus, cooled from about 75 deg. to zero Fahrenheit, has its focal length increased by one-half per cent.

"Such a variation, which frequently is aggravated by a contraction of the body of the camera, is detrimental to the sharpness of the image and introduces an appreciable error in the use of aerial photographs in surveying. A French patent granted to the *Société d'Optique et de Mécanique de Précision* provides against this variation by a compensation between the thermic effects on the glasses by the thermic effects on the mount, made of concentric tubes of brass and 'invar' metal. Minor variations of the focal length are a consequence of varying the aperture of a lens containing some residues of a spherical aberration, but an easy remedy is the use of a fixed diaphragm. Some lenses have been disabled by an interversion of their respective parts due to the fact that the number of the lens was engraved on one part only of the mount."

TYPICAL LENSES

The makes of some of the lenses in general use to-day are as follows :

British.
- Airo Xpres . (Ross, Ltd.).
- Aviar . . (Taylor, Taylor and Hobson).
- Aldis Triplet . (Aldis Bros.).

American.
- Hawkeye . (Eastman Kodak Company).

France.
- Berthiot's Olor.

German.
- Carl Zeiss-Tessar.

LENS SCALE

For vertical photographic work or for mapping, the lens of a particular focal length should be selected according to the flying height necessary to give a definite scale on the negative. The scale of the

image is directly proportional to the focal length and inversely proportional to the altitude. The formulæ adopted for ascertaining the unknown quantity, whether it is the scale of negative, flying height essential to give a pre-arranged scale, etc., are dealt with later.

LENS FORMULÆ

Symbols used :—f focal length of lens in inches.
z diameter of disc of confusion of the lens.
I approximate infinity of the lens in inches.
N hyperfocal distance in inches.
F diaphragm number (English system).

NOTE.—The disc of confusion is the maximum size of disc or point of which a sharp picture can be composed. Usually 1/100″ is taken for the diameter, but when the photograph is to be enlarged it would be safer to take 1/200″ or 1/300″.

To find distance of infinity point of lens.

$$I = \frac{f^2}{z}$$

To find the hyperfocal distance (*i.e.* the distance beyond which all objects are in sharp focus) when the lens is set for infinity.

$$N = \frac{f^2}{F \times Z}$$

CHAPTER VII

FILTERS

UNDER the section dealing with haze and colour sensitiveness, we have referred to the subject of light filters. Light filters are introduced mainly to eliminate haze and secondly to give a reasonably correct tone and colour rendering.

The filter is made either of dyed gelatine, or is in the form of special tinted glass. It may be of yellow or other colour. The filter is used behind, before, or between the combinations of, the lens. For aerial work it is not necessary to use the usual fully corrected panchromatic emulsion, but one which is not so sensitive to green but more sensitive to blue. This applies specially to work over open countryside—to show a certain degree of contrast in field colourings.

THE PURPOSE OF A FILTER

The purpose of a filter is to compensate for the abnormal sensitiveness of the photographic plate to the blue and ultra-violet rays which are always present in daylight. The ultra-violet rays are completely absorbed, and the blue-violet are absorbed to a greater or lesser extent, according to the grade of the filter. Blue-violet and ultra-violet rays affect the plate more than any other type of ray. The latter are invisible, and to this fact and to the inability of any plate other than the Panchromatic of recording the red rays, is due the lack of faithfulness of the rendering of colour values in ordinary forms of photography.

Light filters are most important in the taking of photographs from the air, and the optical equipment of an aerial camera is not complete unless it is provided with interchangeable filters of various densities. Yellow, orange and red stained filters are introduced according to the

type of plate used, and according to the subject and the conditions of the atmosphere. The gelatine type of filter is often cut to fit the lens in use and then placed between the lens combination. This is not a method which can be strongly recommended, as in this form the filter is easily damaged. At the same time, it is no simple matter to obtain a film which is entirely free from irregularities in thickness. It is much better to have the filter cemented between optically worked glass and carried in a metal mount.

MOUNTS

From our own experience we have found it distinctly preferable to have a mount which will screw successfully into the front of the lens, so that there is very little likelihood of its working loose from the camera during its passage on the aeroplane or aerial platform. In some instances, a special filter carrier is fitted on the camera. This obviates the necessity of making a filter for any particular type of camera. Mountings for the screw can be so arranged that any one of a series of filters can be utilized, the exchanges being easily effected. All cameras should be re-focussed after new filters have been inserted.

In some makes of cameras, the Ica for example, filters of glass are screwed into a metal holder supported in front of the lens. A hand-control enables the filter to be swivelled into use when required. It is invariably necessary to have a new filter specially selected and tested for optical quality in order to secure the very best definition of lens.

It is necessary to exercise great care in the handling of cemented filters, as it is generally impossible to get the cement as hard in these filters as in the lens, and any uneven pressure or mishandling of the filter may effect the optical efficiency.

Filters in general use give only partial correction, due to the lack of colour-sensitiveness in the emulsion, and usually show up the reds fairly well but leave the greens under-corrected ; but as stated, they completely absorb the ultra-violet rays. See Alpha spectrogram—(Fig. 34.) In a K.2. or an Ilford Alpha, the increase of

PLATE No. 14.

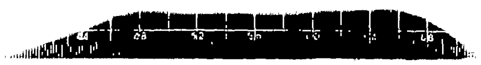
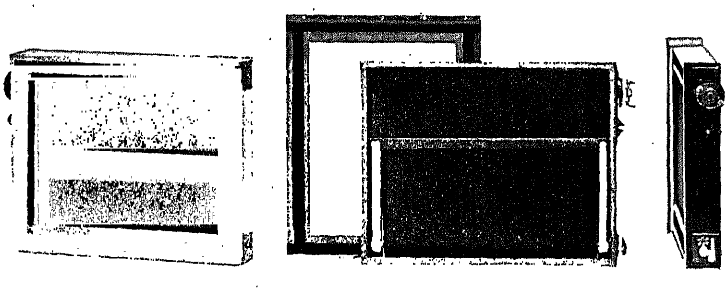


FIG. 34. SPECTROGRAM OF THE ALPHA FILTER.

The Alpha filter is generally used with the Ilford Special Rapid Panchromatic Plate. It gives partial correction showing the reds and blues approximately corrected, leaving the greens under corrected and absorbing the ultra-rays completely. The increase of exposure is about 2 for average daylight.



(*Gaumont.*)

FIG. 35. GAUMONT FOCAL PLANE SHUTTER.

To face page 68.

exposure is only about 2 for average daylight while it is much less than that for yellow light. They give most satisfactory results in the elimination of normal haze. Whenever it is possible to increase exposure, denser filters can be brought into operation. In this case we recommend the K.3. or the Micro 5—which are still more effective for cutting out haze.

Forestry surveying depends very much upon suitable filters to reveal the differing shades of green and brown, and in a later chapter we shall show how such a filter provides valuable information concerning the earth's surface as viewed from the air.

In this country the filters equivalent to the Eastman K.2. give very satisfactory results, but in America and the Colonies, an effective contrast is secured by the use of a much heavier filter, such as Eastman-Kodak Aero No. 1, Aero No. 2, No. 12 and No. 25, K.3.

Exposure Factors as determined by the Eastman Kodak Research Laboratories for their Respective Filters and Plates.

Filter.	Panchromatic Plates.	Extreme Red Sensitized Panchromatic Plates.	Panchromatic Film.	Hyper-Sensitized Panchromatic Film.	Aero-Ortho and Orthochromatic Plates.	Extreme Sensitive Orthochromatic Plates.
Aero No. 1	2	$1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$	5	3
2	3	$2\frac{1}{2}$	4	$2\frac{1}{2}$	6	4
12	6	4	8	4	20	8
25	12	6	14	6	—	—

Only the most sensitive Panchromatic materials under brilliant lighting conditions can be used with No. 12 and 25, the strongest filters. Under the best conditions of lighting either of these filters could be used with panchromatic plates, but as films are somewhat slower the use of a stronger filter than No. 12 is not adviseable. When the light is inferior it is advisable to use hyper-sentitized materials. Under good conditions of lighting and with strongly orthochromatic films or plates, the filter known as No. 2. may be used with considerable success. Aero No. 1 is the standard filter for material with lower colour sensitiveness.

Exposure Factors for British Filters.

Manufacturers.	Plate.	Name.	Visual Colour.	Factor.
Ilford, Ltd.	Special Rapid Panchromatic	Alpha	Yellow	2
do.		Beta	Pale yellow-green	3
do.	do.	Micro	Orange	$4\frac{1}{2}$
Imperial . . .	B. Panchromatic	Impan.	Yellowish-green	$2\frac{1}{2}$
Wellington & Ward .	Spectrum	No. 2.	Yellow	2
do. do. .	do.	No. 3	Yellow	3

Any of these filters can be strongly recommended for use in this country but it is advisable to adopt the filter suggested by the manufacturers of the plates in use.

By the use of Panchromatic plates or films together with filters, corrected renderings of colour values in their respective order may be obtained. The explanation of the term "colour value" should be understood to mean the tone by which the colour is represented on the photographic print; and also by the correct colour values the rendering in monochrome (that is, one colour) of a picture in which various colours of the original are represented in corresponding depths as seen by the human eye. The variations in colour correspond to the relative brightness acting upon the lens of the camera.

Filters vary according to their colour and do not depend upon the varying depths of one individual colour. According to their penetrating power they vary in density and this will effect the length of exposure. The greater the correction the longer will the exposure be.

CHAPTER VIII

CAMERA SHUTTERS

The problems surrounding the use of the camera for work from the aeroplane are many, and a new set of factors is brought into being. The action of taking a photograph of a fixed object from a moving base such as an aeroplane, is not quite the same as taking a photograph of a moving object from a fixed base.

As an aeroplane must necessarily travel at high speed and as the chassis on which the camera is supported is in a state of violent vibration the exposures which may be given must be curtailed to ensure minute sharpness in the finished picture—this is to allow of considerable enlargement.

LIMITATIONS OF EXPOSURE

The limitations of exposure are controlled by (*a*) the speed of the aeroplane over the ground, (*b*) the type of lens used (*c*) the speed of the sensitized plate or film and finally (*d*) the value of light.

These limitations make an efficient shutter an essential to successful work. The shutter must secure the maximum light giving power for any specified length of exposure.

With modern high speed lenses and increased sensitized material we are not so handicapped to-day as during the war when aerial photography was in its infancy. Even under adverse weather conditions and poor light, satisfactory results both in speed and contrast can be achieved with the materials now in use.

The minimum exposure, which has been arrived at after much experience of the conditions prevailing, is 1/50th of a second—the least which should be given for any photograph, irrespective of lighting conditions, state of atmosphere, and height of 'plane.

EFFICIENCY FACTOR

The most general type of shutter used is the *Focal Plane*, so called because the shutter blind works as close as possible to the focal plane of the plate, thus ensuring the highest possible efficiency. When dealing with comparatively rapid exposures, the efficiency factor is of the utmost importance as it is essential that as many light rays as possible should, after entering the lens, pass along to the sensitive plate to assist in building up the photograph.

The term efficiency is used to denote the proportion of the time of the total exposure—when the lens is fully uncovered, permitting all effective light rays to pass through the plate. This proportion varies with different types of shutter.

In the case of the focal plane shutter it will be seen that only a small portion of the plate is exposed at a time ; the time of the exposure is based on the time occupied by the slit in passing over a portion of the plate equal to its own opening. Thus, suppose it takes the blind 1/10th of a second to pass over the complete surface of the plate, which for the sake of demonstration, we will say is 4″, and that the width of the slit in the blind is 1/5″ then the exposure given will be 1/200th of a second.

A point which must be borne in mind, when the focal plane shutter is used, is that the lens is always fully open according to the diameter of the diaphragm ; consequently, all the light rays entering the lens are enabled to pass umhampered to the sensitive surface. This, and the fact that the blind is working fairly close to the sensitive plates, makes for added efficiency.

The total efficiency of the focal plane shutter is estimated at between 90% and 95%. It is sometimes argued, however, that it gives uneven illumination because of its variation in speed of the curtain at different parts of its travel. There is certainly the acknowledged focal plane distortion but in practice this does not handicap air mapping.

An average shutter of the *between-lens type* (that is, a shutter working between the components of the lenses close to the diaphragm), 50% of the total time of exposure is occupied in uncovering the lens, thus only allowing 50% of the total exposure time when the lens is fully open. The total exposure time of a shutter is calculated from the time the shutter blades or curtains begin to move, to the moment when

they are at rest, and the ideal shutter would be, therefore, one in which the blades or curtains opened and uncovered the lens in the shortest possible space of time, and closed and covered the lens as swiftly. Such a shutter would have an efficiency value of approximately 100%, a position which obviously has yet to be reached.

The Fairchild shutter of this type which has been specially designed for aerial work claims an efficiency of 60% at 1/50th of a second, 75% at 1/100th and 95% at 1/150th.

It is generally agreed that the ideal shutter has yet to be discovered. The between-lens shutter is impracticable for large apertures and the focal plane shutter, as previously explained, suffers from other faults, but one is led to hope the latest development of an entirely new type of camera shutter, known as the Louvre shutter, will prove a decided improvement.

Here is a general description of a number of shutters:

TYPICAL FOCAL PLANE

This consists of a shallow box having apertures in the front and at the back (in this country a popular model is made by the inventors, The Thornton Pickard Manufacturing Company Ltd.), as large as the plate in use. The box fits in the body of the camera, and to the back piece are fitted the rails which carry the dark slide and focussing screen. At the top and bottom of the box there are rollers, the lower of which is fitted with a spring usually actuated by an external knob. To these rollers is attached the blind, which has an adjustable slit (a narrow rectangular slit) or aperture through which the exposure is made.

The adjustment of shutter speed is accomplished in two ways : One, by having a variable spring tension on the blind, causing it to travel at the desired speed, according to the tension of the spring ; two, by varying the width of the slit.

When resetting the shutter to cover the slit, a self-capping blind comes into operation, thus preventing the plate from being fogged. In some cameras, focal plane shutters without self-capping blinds are used, in which case a movable flap is fitted to the inside of the body, and this flap automatically closes for the protection of the plate, while

the shutter is being wound up. Some types of shutters have a fixed aperture only, when the variation of exposure is provided by the adjustment of the speed of the blind. There are in France, Germany and America other makes of focal plane shutters, most of which are removable units distinct from the camera. (Fig. 35, facing p. 68.)

BETWEEN-THE-LENS SHUTTER

The system of overlapping metal leaves as universally employed on the amateur's camera is adopted. These sections are controlled and opened to make the exposure. There is much controversy as to their suitability for aerial work but it must be said that the Fairchild Corporation have for many years successfully operated this type of shutter.

The Fairchild shutter is said to be the first high speed between-the-lens shutter of large aperture to be perfected. The shutter leaves are in a housing built between the front and rear combination of the lens carried in a cone which attaches to the main camera body. The cones containing either 12″ or 20″ shutter, are interchangeable on the same body for various focal lengths of lenses. The 12″ shutters have three speeds—1/50, 1/100, and 1/150; and the 20″ provide the latter two only. The fine leaves in this shutter make a complete revolution when they are tripped, and swing open and close to give the smallest amount of shock. The retard mechanism, which is operated by an inertia device, comes into operation when the leaves are fully open and disengages before they close; the opening and closing are thus carried out at high speed, increasing the efficiency over and above the common plunger.

"ICA" SHUTTER

The shutter is a removable unit and has set speeds of 1/90, 1/180, 1/375, 1/750 seconds, for which four aperture slit adjustments are made. The tension of the spring is a fixed one, but this can be adjusted. The winding head of the blind is moved in stages from the lowest to the highest speeds of exposure and by a neat device any or either of the four slits can be fixed. An indicator shows the markings of speeds,

according to the setting of the blind. A capping device is provided by two shutters which open into the body of the camera during exposure.

"AEROPHOTE" PATENT S.G.D.G. SHUTTER

This shutter is a type quite distinct from any other type already described. It is really part of the Aerophote camera itself, and is also employed in moving forward the film after each exposure. It is known as the "shutter carriage" and is more fully described with the details of the Camera on page 96. The opening is a fixed one and the speed is varied through the electrical gear by a magnetic brake. Exposures of 1/75, 1/100 and 1/200 may be made.

Its chief advantage is that the slit or aperture travels directly in front of the focal planes, almost in contact with the film. It is claimed that a luminous efficiency of 100% is secured whilst the film is kept flat with 1/20th of a mm. of truth without either suction or interposition of glass.

THE RENITION SHUTTER

Apparently this type of shutter was introduced in 1921 by the Compagnie Aérienne Française and has been successfully used by them for some years. The patented particulars are as follows:

The shutter is formed with two screens, each having a series of parallel, equal and equidistant slits. The screens lie close to one another above the plate, with the slits in each screen covered by the opaque portions of the other. In exposure, the two screens are set in motion so that the series of slits give rapidly opening and closing apertures, each of which exposes a single band of the plate. Thus, a very small movement of the screens exposes the entire plate and the movement is so adjusted that the exposure is entirely uniform at all parts of the plate.

The arrangement of the screens is shown in Fig. 36 (p. 77). The screens Ra and Rb are actuated by means of springs 1 and 1′ placed parallel to the direction of displacement. In the position shown, with the shutter set for exposure, the two screens are held so that no aperture

is left and the springs are both under tension. To make the exposure, the hook 4 is depressed out of engagement with the contact 6 and, thus freed, the screen moves to the right under the action of the spring 1, thus opening a series of apertures. When this screen Ra has travelled a certain short distance, the projection 7 meets the arm 6′ and moves it so as to release the screen Rb from the finger 4′. The screen Rb then moves, under the action of the spring 1′, towards the right. The two screens thus move simultaneously at different speeds until they are both brought to rest in the second closed position.

THE "STRINGER" LOUVRE SHUTTER

Composed of a number of narrow metal strips, this shutter is mounted in such a way as to rotate about axes in their own planes, thus effecting an exposure on the " Venetian blind " principle. The shutter is immediately in front of the plate or film. No part of the plate is masked by the exposure, as during the rotatory movement of the strips, the axes are moved laterally.

To produce the rotation of the strips two long racks, one fixed and one movable, mesh with pinions mounted at either end of the axis of each strip. By reciprocating the movable rack the strips are both rotated and moved transversely. See diagram. The shutter is constructed wholly of metal, thus ensuring strength and reliability in operation. (Fig. 37.)

It is anticipated that this shutter will overcome the known faults of the focal plane shutter and prove superior to the between-lens shutter which, by the way, is considered by some to be impracticable for lenses of really large apertures. It is understood that this shutter is to be introduced into the " Eagle " Survey Camera.

SHUTTER RELEASES

Shutter releases on oblique cameras are placed on the body in a convenient spot for easy operation by the fingers; slight pressure is sufficient to work them. The device consists of a trigger with a tripping action which releases the tension spring.

In the vertical cameras, where the camera is fitted some distance from the operator, Bowden wire connections are brought into use. For automatic release set to a perspecific time interval in seconds, the operation is carried out by electricity, a dial registering the setting and release for the photographer's information.

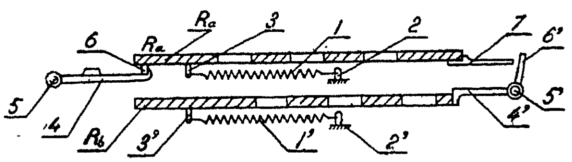


Fig. 36. The Renition Shutter, showing arrangement of screens.

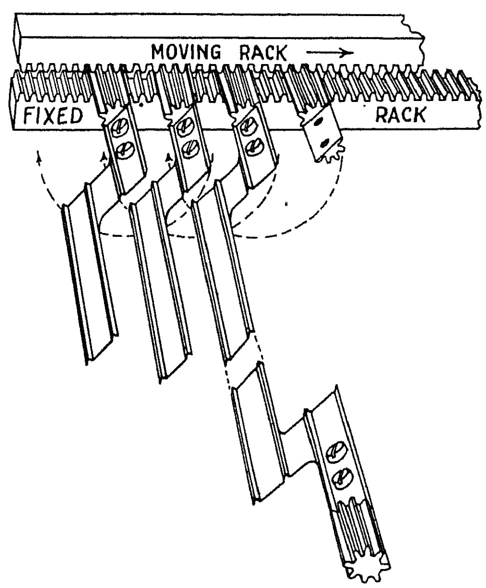


Fig. 37. The "Stringer" Louvre Shutter.

CHAPTER IX

CAMERAS

OBLIQUE AND VERTICAL NON-AUTOMATIC CAMERAS

THE "A" AERO (*PLATES*)

THE original camera of this type was the first British aero camera made by the Thornton Pickard Manufacturing Company. It was a war camera and is still manufactured, with the addition of certain improvements which were introduced for commercial reasons. The body is of wood, with handling straps, and accommodates an 8 inch to 10 inch lens. A self-capping focal plane shutter is a feature, and at the back of the camera provision is made for the Mackenzie Wishart plate carrier which holds the envelopes carrying the 5 × 4 plates. When the light-proof envelope is placed in the carrier and the back flap is closed and locked, the slide is pulled out, thus drawing the blind from the face of the plate. This slide can be folded and buttoned to the back of the camera. After an exposure the slide is pushed back. The envelope may then be removed. The shutter and slide are pre-vided with fool-proof devices as a safeguard against the inadvertent fogging of the plates. The usual shutter adjustments can be made and a metal tubular view finder is supplied. (Fig. 38.)

"P" TYPE AERO (*PLATES*)

This hand-held plate camera is one of the types most commonly used for oblique work in Great Britain. It was first introduced during the War and is still in the service of the Royal Air Force. It consists of a metal body and fixed cone holding an $8\frac{1}{2}''$ to $10\frac{1}{2}''$ lens, and as in the aforementioned type includes a self-capping focal plane shutter with variable slit and detachable plate-holder for the Mackenzie Wishart envelopes, size $5'' \times 4''$. The blind has a fixed tension. A knob at the side controls the slit adjustment. The shutter is set by means of

PLATE No. 15.

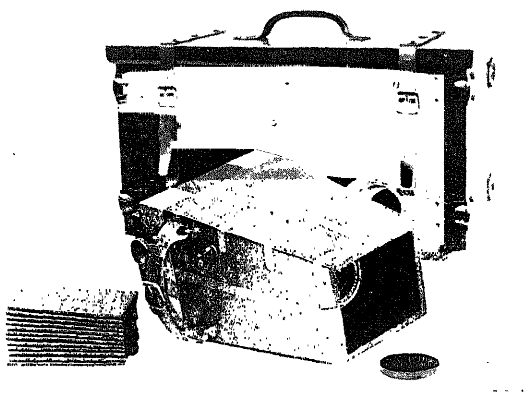


FIG. 38. "A" TYPE HAND-HELD PLATE CAMERA.

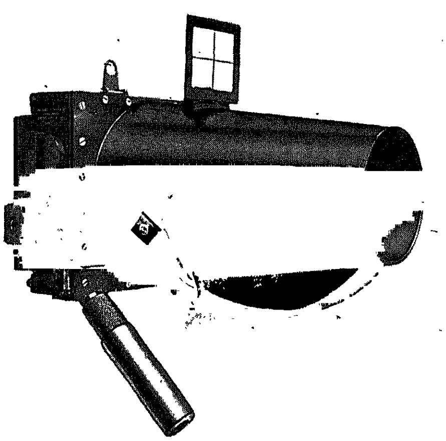


FIG. 39. "P" TYPE 5 IN. X 4 IN. HAND-HELD CAMERA.

To face page 78.

PLATE No. 16.

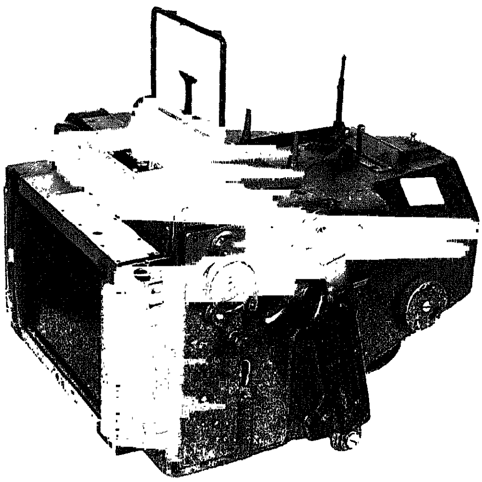


FIG. 40. "ICA" 13 X 18 CM. CAMERA, WITH ERNEMANN PLATE MAGAZINE IN POSITION.

To face page 79.

a winder fitted with a frictional detent, which, while preventing injury from over winding, enables the user to be certain that it is fully wound.

A supporting handle of wood is attached on the right hand side and alongside this is a conveniently placed trigger. The left hand of the operator is slipped under the cone and through a leather strap. An open sight, which folds down when not in use, is provided. The manufacturers of this camera are Messrs. R. W. Munro Ltd., of Tottenham, London. (Fig. 39.)

THE "ICA" (*PLATES*)

A German war camera, the Ica, is still in use. Its body is octagonal and is made of canvas-covered wood. An Ica shutter (as previously explained) is fitted, and in front of the lens is a mount for accommodating any particular density of filter required, which by the bayonet joint fitting may be brought into use at any desired moment.

The Ernemann Magazine carries six plates (13 × 18 cm.) and plate changing is effected by withdrawing and returning the end of the magazine.

Stable and sensible handles and grips are supplied for holding the camera, which together with mechanism is a very creditable piece of work. An excellent open sight is provided.

The Ica is made in various sizes, the largest taking a 20″ lens. The bigger cameras are of course all mounted on aircraft and not carried by hand, an outside lever being fitted for the setting of the lens diaphragm.

A similar camera, now manufactured by "Aerotopograph" of Dresden, is used in conjunction with photographs taken for the Aerocartograph and Autocartograph processes. (Fig. 40.)

GAUMONT (*PLATES*)

The size of plates accommodated in the French Gaumont production is 18 × 24 cms. The camera, with aluminum body, is obtainable in three sizes for lenses of a focal length of 300, 500 and 1,200 mm.

The smaller sizes are fitted with handles at the sides of the body

in order to provide a good grip for hand operation. The larger size is designed for suspension in a mounting.

The shutter has an adjustable slit and tension for exposure from 1/45 to 1/500 of a second. It is released by a lever or Bowden wire attachment. The magazines hold 12 plates, to change which the end of the magazine is pulled out and thrust back.

The exposed plate, on being withdrawn, is forced up behind the unexposed plates by strong springs. Behind the lens there is a protector screen which automatically opens prior to the release of the shutter. (Fig. 41).

THE DE MARIA CAMERA (*PLATES*)

This French war camera is still operated by many photographers. Various sizes are made for hand-holding and for mounting on aircraft with lenses from 26 cm. to 120 cm. The plate size is 13 × 18 and 18 × 24 mm., twelve plates being carried in the "de Maria" magazine which operates the plate changing in the same way as the Gaumont and Ernemann (Ica Camera). The Klopcic type of shutter is used. It has a varible tension and aperture, and is self-capping.

The body is of metal and an open sight may be fixed on the top or bottom of the camera. Two handles are provided, alongside of one of which is the finger release.

The hand-held type with "de Maria" magazine has to be pointed lens upwards during the operation of plate changing, but to obviate this in the larger types a Gaumont magazine is fixed. The exposure is made by Bowden wire release.

AEROPHOTE G.R. 1925 MODEL (*FILMS*)

The G.R. 1925 model is designed for oblique photography—with 200 exposures on each film. Size of picture 13 × 18 cms. The film is moved round by an outside handle and an indicator shows the number of exposures made. It has an open sight and trigger release. Lenses of 210, 250 and 300 mm. may be fitted.

PLATE No. 17.

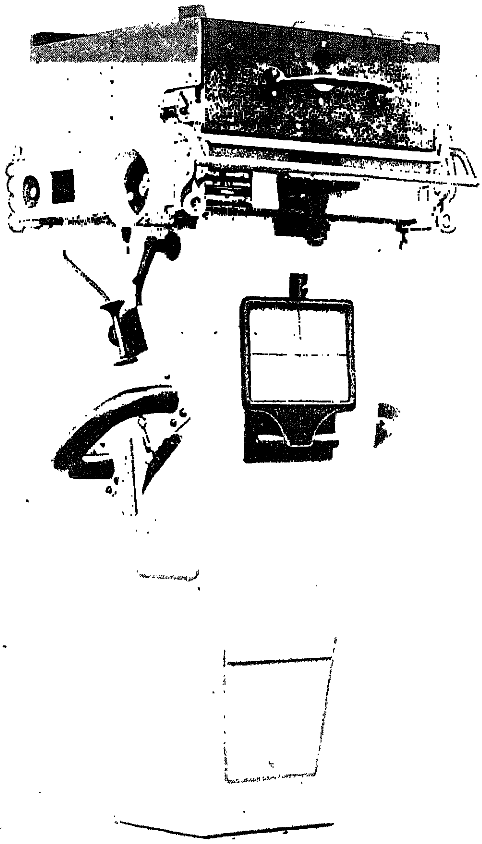
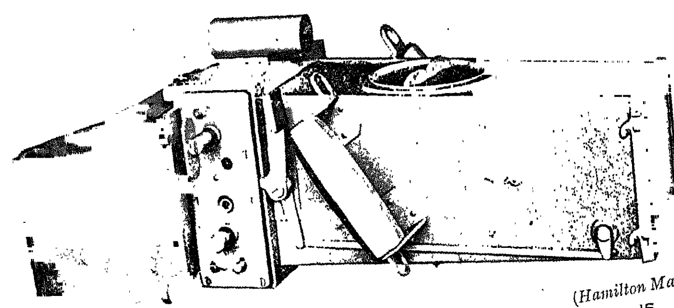


FIG. 41. GAUMONT CAMERA. THIS TYPE TAKES A 500 MM. LENS. THE MAGAZINE HOLDS TWELVE 18 X 24 PLATES.

To face page 80.

PLATE No. 18.



(*Hamilton Maxwell*)

FIG. 42. EASTMAN A-1 CAMERA. A GRAFLEX MAGAZINE IS FITTED FOR PLATES OR CUT FILMS.

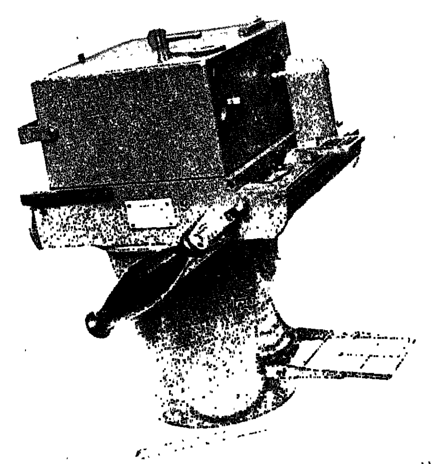


FIG. 43. AERO P.F. FILM CAMERA FOR HAND-HELD WORK ALLOWING FOR 60 EXPOSURES.

To face page 81.

EASTMAN A.1. (*PLATES AND CUT FILMS*)

The U.S. Air Service have used the Eastman A.1. extensively. It is designed for hand use and is held by two side grips with a thumb lever shutter release which causes a safety shutter to open just before an exposure is made.

The body and cone are of aluminum and a direct vision tubular finder with interacting vertical and horizontal wires is fitted for sighting. A 10″ Hawk-eye lens, with f4·5 aperture, is supplied. Exposures of 1/120 to 1/435 of a second can be made by the adjustment of the tension of the focal plane shutter which has a fixed slit. A Graflex magazine holder is fitted. It holds twelve plates, size 5″ × 4″, or cut films loaded in sheaths. This may be classed a bag magazine in which the exposed plate is pulled out by a metal slide into the light-proof bag; on being pushed back, the plate and sheath are lifted and pushed in the back of the magazine. An indicator reveals the number of exposures made. (Fig. 42.)

THE EASTMAN B.1. (*FILMS*)

This is intended for oblique work and its design is similar to the Eastman Model A.1. It is an improved model and is used for films only. It takes a twelve exposure 5″ × 4″ film roll which can be loaded in daylight.

The focal plane shutter is set and the film wound ready for exposure by the turning of a lever. The total weight is only 10 lbs.

THE AERO P. F. (*FILMS*)

The main use for this film camera is for hand-held work and oblique photography. Its total weight complete with main shutter and sufficient film for 60 exposures is only 12½ lbs. In shape it is somewhat similar to the usual form of plate camera, *i.e.* a tapered aluminum lens cone is cast with a rectangular chamber to hold the focal plane shutter and gearing. This forms the body of the camera to which the magazine as a separate unit, can be quickly attached or detached. The body is provided with a folding open type view finder and is fitted with two

hand grips, the right hand of which is fitted with a trigger for making the exposures, whilst the left hand is swung through 90° for operating the film mechanism and shutter with one movement. By this means photographs can be taken in rapid succession without the necessity for removing the hands from the grips, or setting the camera down. Immediately above the focal plane shutter an optical glass plate is secured which is engraved with four points accurately collimated with the lens in position. At the moment of exposure the film is pressed flat against this glass by a spring-loaded pad operated from within the magazine. The camera is manufactured by the Williamson Manufacturing Co. Ltd. of London.

The magazines are fitted with light-tight slides and can be loaded either in the dark room without black paper on the spools or if provided with sufficient lead could be loaded with care in the daylight.

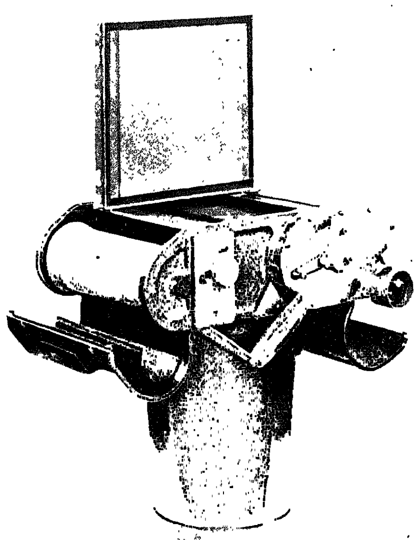
When fully loaded these hold 25 feet of film 4″ wide: sufficient for 60 exposures. They work equally well if the emulsion is wound inwards or outwards but unless a recognized standard is adopted it is necessary to mark the black paper leads in order to avoid incorrect threading up.

Incorporated in each magazine are (1) A Pressure Plate (2) Film Travel Controller (3) Number Indicator.

(1) *Pressure Plate.* This is controlled automatically when using the camera, but is operated by the " spade " shaped lever on top when loading or unloading. To lift the plate throw the lever over towards the back, and vice versa.
(2) *Film Travel Indicator.* This is automatic in action and regulates the spacing between the consecutive pictures.
(3) *Number Indicator.* This is reset to Zero by pressing the button on top. In indicates to " 58 " exposures only.

The only adjustment possible is in the width of the slit. This is controlled by the brass knob and slide at the rear of the camera: in the zero position the shutter does not open: at 4 the opening is 1½″. The shutter may be detached.

The travel of the film and the correct setting of the shutter depend to a large extent on the movement of the pivoted operating handle. It is provided with a safety trip pawl which prevents the handle returning to its position of rest until the completion of the stroke, but



(*Hamilton Maxwell.*)

FIG. 44. EASTMAN K-5 HAND OPERATED FILM CAMERA.

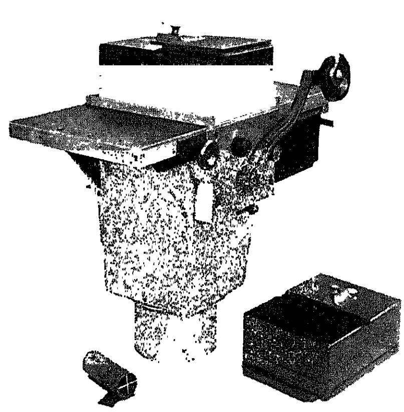


FIG. 45. "C" TYPE AERO 5 IN. X 4 IN. PLATE CAMERA.

To face page 83.

should be moved steadily to the fixed stop in each direction to ensure correct functioning of the various parts. (Fig. 43, facing p. 81.)

THE EASTMAN K2 (*FILMS*)

This oblique camera for roll film 9½″ wide by 75 feet long is hand operated and in construction it is similar to the K1 model, which will be later described fully, with the exception that in place of a wind motor there is a winding crank.

When the crank handle is turned the shutter is reset and a new section of film is brought into position. An ordinary trigger release is supplied and on a 75 foot length of film one hundred exposures are possible. The film is held flat by suction from the Venturi tube mounted on the outside of the fuselage. The speed of the focal plane shutter can be varied to give from 1/45 to 1/155 of a second exposure. A 20″ f4·5 lens is supplied and the mount is arranged to receive compensating filters.

A mounting on a swivel fixed to the fuselage is provided to ensure movement in all directions. To eliminate vibration the front of the cone is held between two arms by an elastic cone suspended on the mount. A brilliant type view finder is affixed to the cone. The camera, including lens and one film roll, weighs 40 lbs.

THE EASTMAN K5 (*FILMS*)

This is a recent model and a combination of the K1 and K2. It is similar in appearance to the K1 except that it is not automatic in action and is operated as in K2 by hand for film, wind and shutter release. It can be used for oblique or mapping work. (Fig. 44.)

MODEL "C" AERO CAMERA (*PLATES*)

The model here described, originally constructed of wood, takes plates 5″ × 4″ loaded in metal sheaths, accommodating 18 in a wood magazine. Any number of loaded magazines may be carried with each camera. It has a focal plane shutter, fitted with adjustable slit to alter the speeds, together with variable spring tension. After

exposure the plates are transferred from the upper loaded magazine to the lower by means of a sliding plate operated by gears from the handle at the side of camera. During this operation the focal plane shutter is reset.

The lens—from 8″ to 17″—is fixed in a cone to focus and is locked in position. A tubular view-finder is attached to the side of camera. The most recent model is made of metal. The manufacturers are: Thornton-Pickard Manufacturing Co. Ltd., Altrincham. (Fig. 45.)

SEMI-AUTOMATIC CAMERAS

AERO-CAMERA TYPE "L.B." (*PLATES*)

A metal camera for vertical photography accommodating plates size 5″ × 3⅞″ with lens from 6″ to 20″; but the usual cones supplied are for 6″, 12″ or 20″ lenses. It is operated by an air screw in the slip stream or by hand. The manufacturers are Messrs. Williamson Manufacturing Co. Ltd. of Willesden.

This camera was introduced towards the end of the War. It is an improved design of the "L" type, which therefore calls for no description. The various units of the camera consist of the body, lens adapter or cone, plate magazine, propeller with flexible coupling, and the Bowden lever release. (Fig. 46.)

A magazine containing the unexposed plates is placed immediately over the exposure aperture on the body, the plates falling into position as required. The exposed plate is moved along horizontally until it is opposite the receiving magazine which is attached to an extension of the camera.

The exposure is made by a focal plane shutter with separate capping device.

The changing of plates and the setting of the shutter are effected in a single operation by the action of a wind propeller or by hand.

The body of the camera contains the plate changer, gear driving mechanism and the focal plane shutter which slides in as a separate unit.

PLATE No. 20.

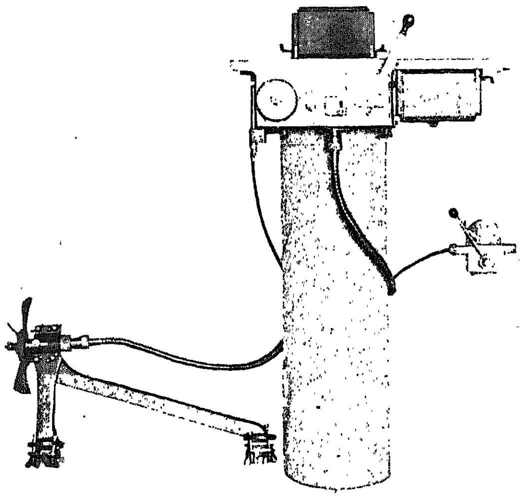


FIG. 46. "L.B." VERTICAL PLATE CAMERA. MAGAZINES IN POSITION. 20 IN. LENS CONE FITTED.

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Over the picture opening on the top of camera table slots are provided to receive the loaded magazine, and also at the end of the plate changer or overhanging table an empty magazine. The cast ring on the underside of the camera is milled to gauge to receive the interchangeable lens cones by the bayonet joint method.

A hand lever is provided for changing the plate and resetting the shutter if required. There is also a trigger to the power drive for release. A switch-over knob determines hand or power control.

The Shutter.

The shutter is of the focal plane self-capping type, contained in a case which slides into an opening at one end of camera where it is held in position immediately in front of the plate. The slit in the blind can be varied from $\frac{1}{4}''$ to $1\frac{1}{2}''$ giving speeds of exposure from 1/600th sec. to 1/100th sec. A pointer indicates the width of the slit.

The Magazine.

The latest type of magazine is of aluminium and brass throughout. Its capacity is eighteen plates which are contained in metal sheaths. An adjustable indicator at the side shows whether the contents are exposed or not. As in the older type, the magazine is closed by a double jointed slide which opens and folds back on the top of the box.

Propeller Drive and Release.

The power is obtained from a small four-bladed propeller held by a bracket facing the slip stream. A flexible drive is connected to the camera. A Bowden wire release is provided to make the exposure. This wire may be of any length, according to the distance between camera and operator. An indicator shows the number of exposures made.

Operation of Camera.

The loaded magazine is placed over the exposure aperture, with an empty magazine in position under the body suspension. The action of the wind propeller through the flexible drive and gearing in the body will set the shutter. After an exposure, which is made by the Bowden

release, the exposed plate now resting in a frame will travel along the overhanging body extension and fall through the well hole into the receiving magazine. At the same moment the shutter will be reset, the whole operation occupying not more than 10 seconds.

The camera is suspended in a "Universal" type of mounting as explained on page 106.

AUTOMATIC CAMERAS

Automatic cameras, representing the latest development of aerial photographic apparatus, embody many improvements devised by manufacturers who have profited by their war experience. While each individual designer has incorporated the best features of his war products he has also added other features which have a special application to commercial photography, and these will be obvious in the outline of one or two cameras to be dealt with in this section. Certainly a number of the cameras to which we shall refer have proved their efficiency in the work of several aerial survey companies, and appreciation is deserved by manufacturers who have adjusted their programme to include the necessities of peace-time photography.

THE "EAGLE" AUTOMATIC ELECTRIC AERIAL CAMERA (*FILMS*)

This British camera which has recently been placed on the market, has been constructed by the patentees and manufacturers—The Williamson Manufacturing Co. Ltd., on experience gained during the last ten years with many types of aerial cameras. The sole selling agents, Messrs. Vickers, of London, claim that with the introduction of modern improvements it is far ahead of any existing camera. This camera and equipment has been adopted for use in the Royal Air Force and is being used by the commercial aerial photographic companies in this country and also by Governments abroad. (Fig. 47.)

The camera is primarily designed for mapping work but single views, oblique or stereoscopic photographs are easily secured with it.

PLATE No. 21.

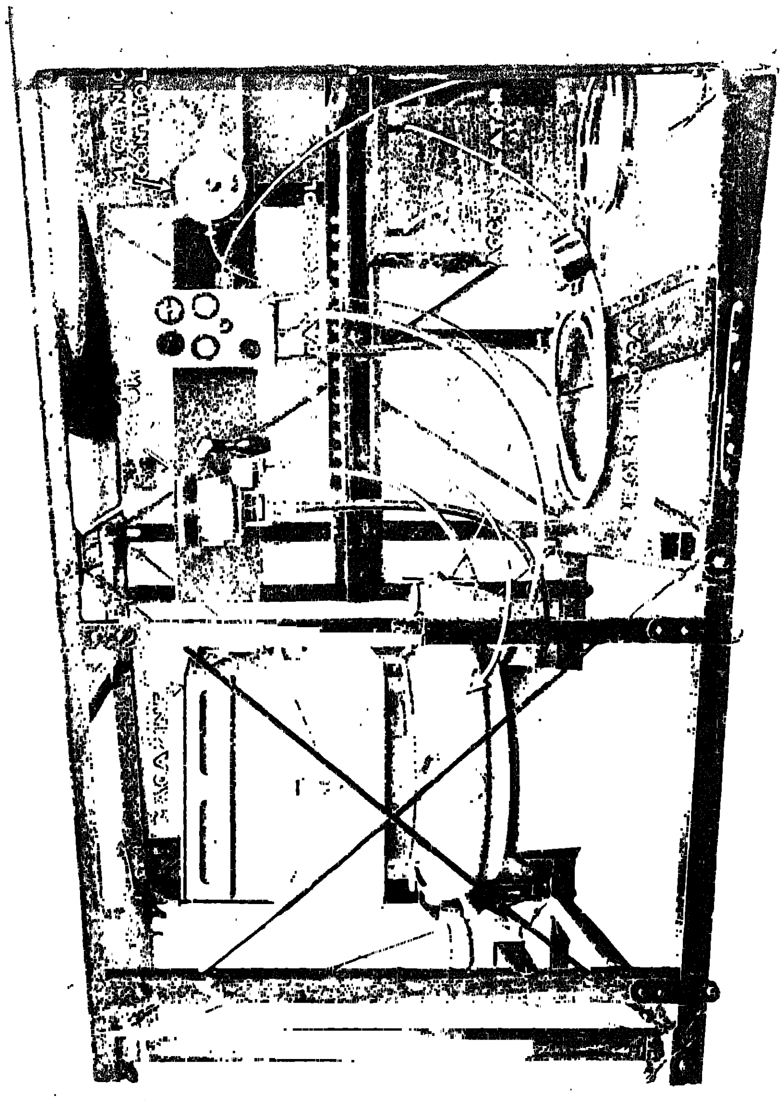

FIG. 47. ARRANGEMENT OF "EAGLE" CAMERA AND EQUIPMENT IN PHOTOGRAPHER'S COCKPIT.

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PLATE No. 21A.

FIG. 48. "EAGLE" CAMERA AND PRINCIPAL UNITS.

To face page 87.

It is strongly constructed of aluminium and duralumin and is calculated to withstand severe and prolonged service. All parts and units are detachable for adjustment and repairs; thus the maintenance of the camera is very much simplified.

A film 9″ (228·5 mm.) wide by 65 feet is accommodated and the size of photograph taken is seven inches square (177·7 mm. × 177·7 mm.) with a record alongside each exposure showing the date, time, height, focal length of lens, number of picture, approximate angle of tilt at the time of exposure, and any data as to the work or contract engaged upon, and lens used. The collimation marks are also recorded on each picture. One magazine provides for 100 exposures which may be taken regularly at any required interval for overlapping—or in single pictures. The Panchromatic film used is manufactured by Wellington and Ward of Elstree.

The operation of the camera (by electrical control, mechanical control or by hand) may be carried out in the following ways:

(1) Completely automatic. By electrical or wind vane units.
(2) Semi-automatic. Either electrical or wind vane will wind shutter, etc., when exposure is made by hand.
(3) Entirely by hand.

It is possible to change over at any moment from one operation to the other.

The interchangeable lens cones hold lenses from 7″ to 20″ focal length. The shutter is of the focal plane type and has a fixed slit and speed. Grading of exposure is by means of iris diaphragm in lens. Magazine-changing is a matter of a few seconds.

The principal units, complete with the camera, include: Lens cone, film magazine, camera body, gear box, focal plane shutter, instrument box, electrical control, pilot's indication lamp, motor unit, windmill, flexible drive, 12 volt battery, voltmeter, electrical leads, fuse box, mechanical control, etc. (Fig. 48.)

The total weight of the camera fitted with accessories, including 10″ lens, electrical and mechanical controls and one loaded magazine is approximately 46 lbs. Here are a few details of the most important units: